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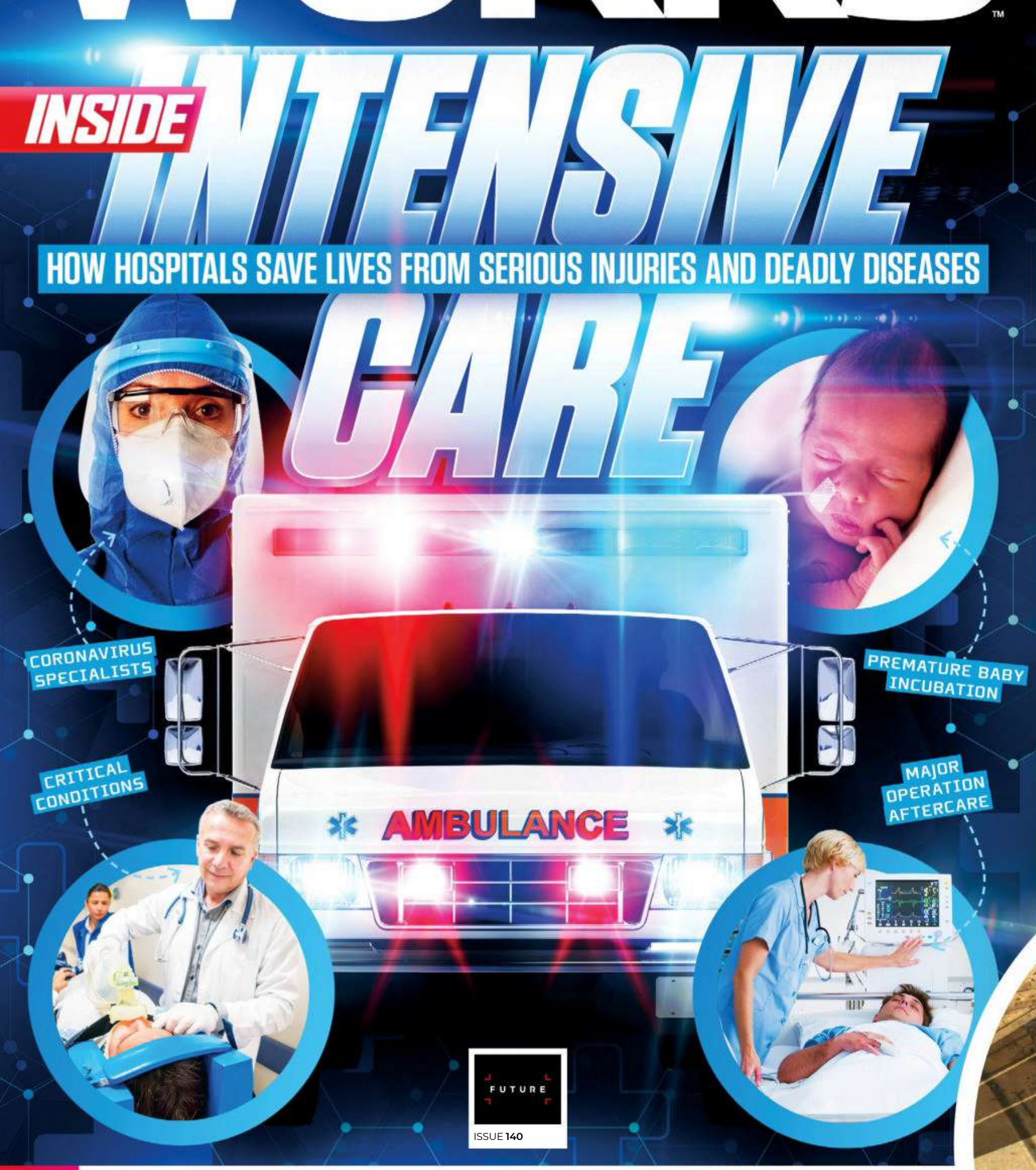

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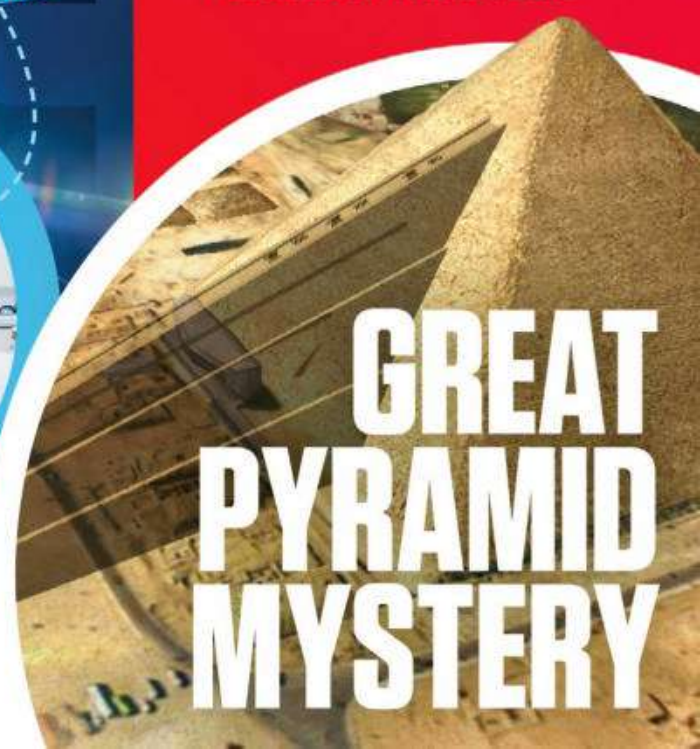
SECRETS OF WWII'S ENIGMA MACHINE



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Audi TT Coupé

The Audi TT takes its name from the successful motor racing tradition of NSU in the British Isle of Man TT (Tourist Trophy) motorcycle race. NSU marque began competing at the Isle of Man TT in 1907 with the UK manager Martin Geiger finishing in fifth position in the single-cylinder race. The 1938 Isle of Man Lightweight TT race was won by Ewald Kluge with a 250 cc supercharged DKW motor-cycle and the DKW and NSU companies later merged into the company now known as Audi. The TT name has also been attributed to the phrase "Technology & Tradition".

The styling of the Audi TT began in the spring of 1994 at the Volkswagen Group Design Center in California. The TT was first shown as a concept car at the 1995 Frankfurt Motor Show and the design is credited to J Mays and Freeman Thomas, with Hartmut Warkuss, Peter Schreyer, Martin Smith and Romulus Rost contributing to the interior design.

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WELCOME

The magazine that feeds minds!

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"We get called to all sorts, from someone with a heart problem to a road traffic accident."

Inside intensive care, page 20

Working in a hospital's intensive care unit (ICU) is similar to being on the battlefield, where the situation can turn on a pinhead and split-second decisions can make the difference between life or death. Can you imagine what it was like when Crimean War nurse Florence Nightingale was pioneering intensive care treatment for wounded soldiers over 150 years ago? Nowadays ICU workers have sophisticated technology and decades of advanced medical knowledge at their disposal, but taking care of critically ill patients is no less demanding, as our interview with the lead consultant of an ICU reveals in our special feature on page 20.

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Ben Editor

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Meet the team...

Nikole
Production Editor
The smallest planet in our Solar System orbits close to the Sun, so is hard to observe. Catch a rare glimpse of Mercury on page 60.

Scott
Staff Writer
How has nature responded to the massive break from human activity during global lockdowns? Find out on page 36.

Baljeet
Research Editor
The pyramids hold many secrets, but the biggest remains around how they were built. Explore these Egyptian enigmas on page 44.

Duncan
Senior Art Editor
Lap up the luxury experienced by the rich and famous out at sea in some of the most extravagant superyachts money can buy, on page 64.

Ailsa
Staff Writer
We often rely on antibiotics to rid our bodies of infection, but some bacteria are rebelling. Meet these superbugs on page 50.

CONTENTS

SPECIAL

20 Inside intensive care
Explore the beating heart of the hospital, where human and machine fight to save lives from critical illness and injury

TECHNOLOGY

28 Superstructures
How clever engineering and technology have seen the rise of the world's biggest skyscrapers

32 Landmine robots

34 How to repel sharks

ENVIRONMENT

36 Lockdown: nature bounces back
How the environment has fared in the coronavirus pandemic

42 Australia's pink lake

HISTORY

44 Mystery of the Great Pyramid
Has a French architect cracked an ancient riddle that has confounded people for centuries?

48 How Enigma made secret messages

SCIENCE

50 The rise of the superbugs
Why the overuse of antibiotics has led to new generations of drug-resistant deadly diseases

54 How does hypnosis work?

58 What are Adam's apples?

SPACE

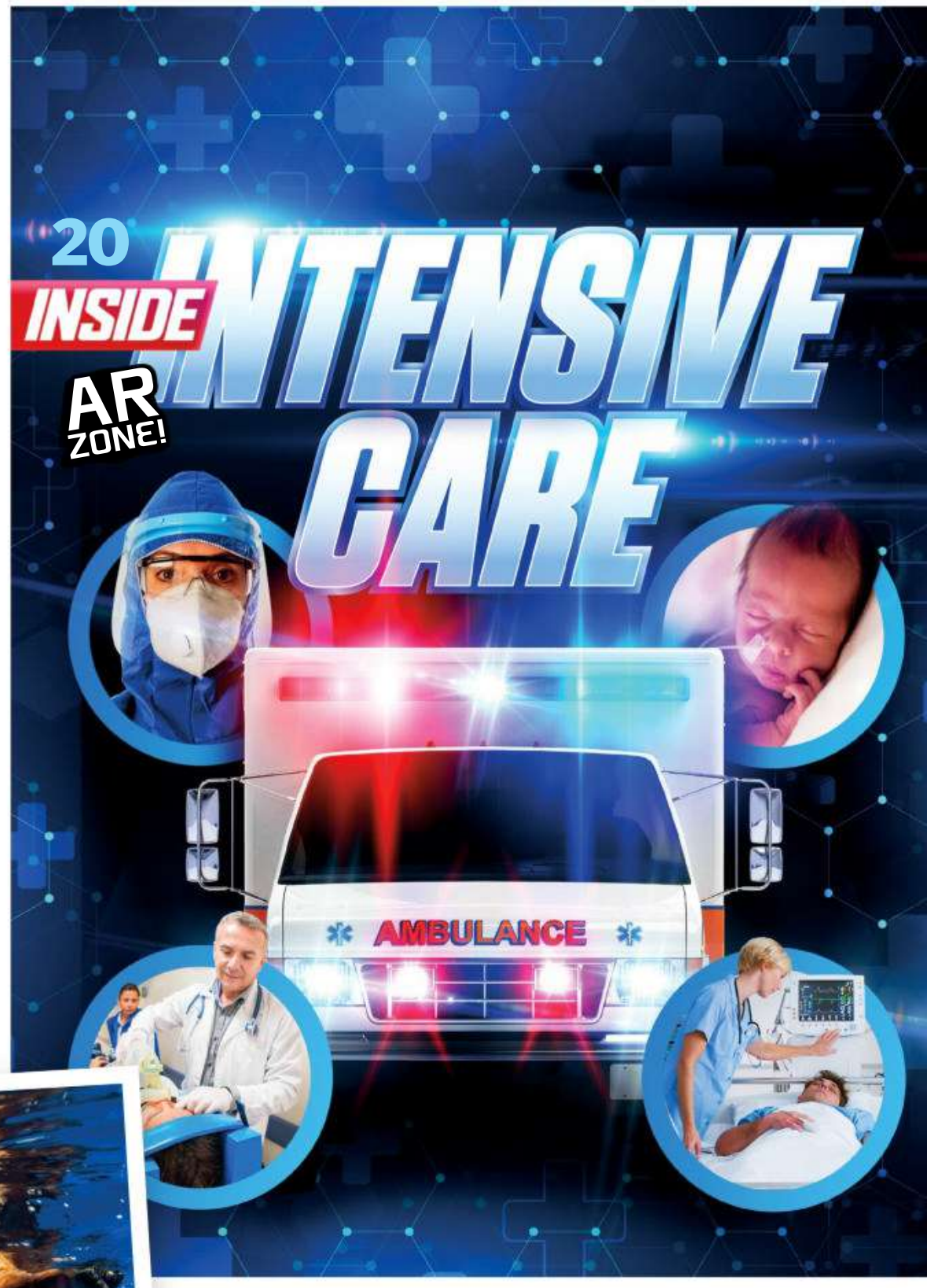
60 Mercury
Discover the closest planet to the Sun, from surface to core

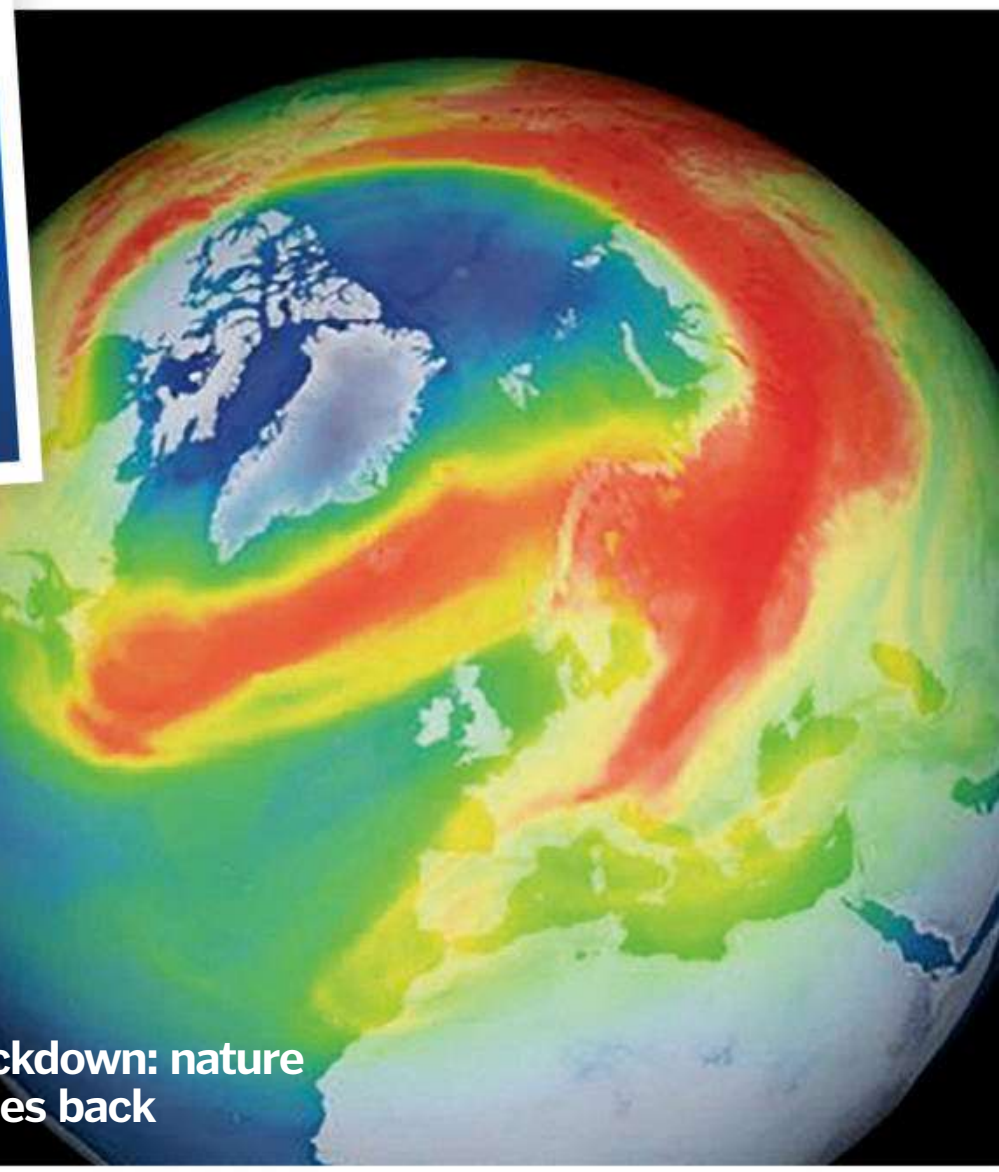
62 The SOFIA telescope

TRANSPORT

64 Megayachts
All aboard these luxury, high-tech boats for billionaires

68 How petrol pumps work





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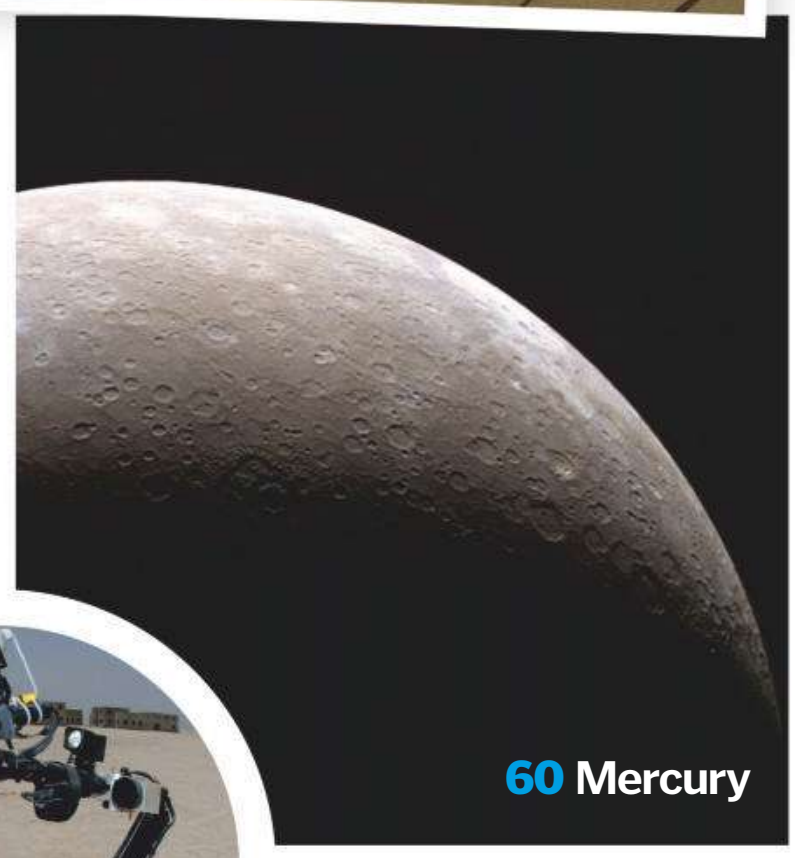
64 Megayachts

44 Mystery of the Great Pyramid

54 How does hypnosis work?

32 Landmine robots

28 Superstructures



60 Mercury

50 The rise of the superbugs

48 How Enigma made secret messages

AR ZONE!

REGULARS

06 Global eye
Science and tech news from around the world

16 Wish list
Get to grips with these home office gadgets and apps

59 Three free eBooks
£30 of **How It Works** digital specials for every reader

70 Brain dump
Your questions answered

74 Book reviews

76 Brain gym
Give your brain a workout with our puzzle pages

79 How to...
Make a tornado in a bottle

80 Letters
Our readers have their say

82 Fast facts

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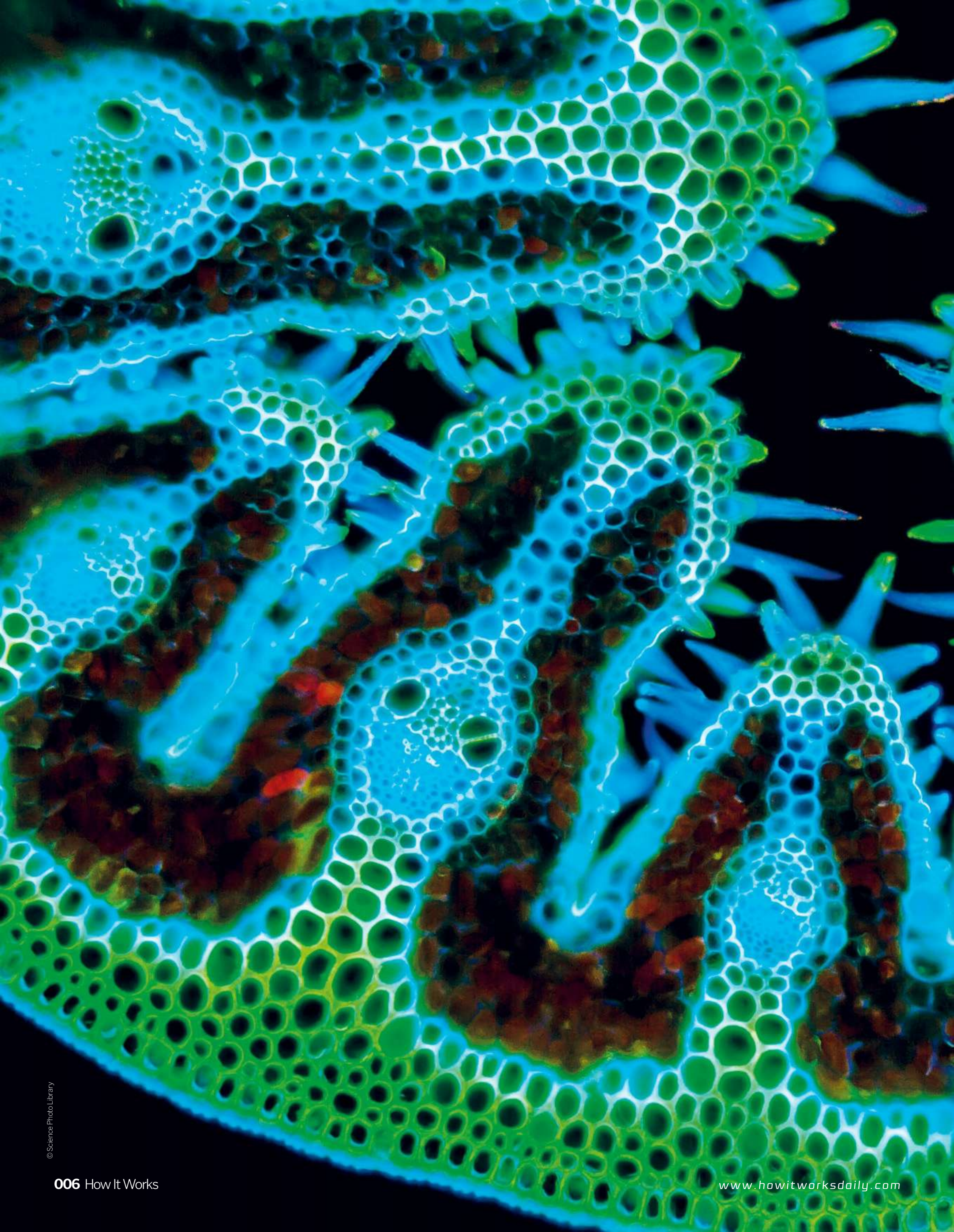

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FACES IN LEAVES

At first glance this image might look like an abstract painting of a queue of people, but in actuality this is the light micrograph of a section of a marram grass (*Ammophila arenaria*) leaf. Found in coastal areas on sand dunes, the survival of this species of grass is dependent on its ability to optimally intake water and store it. Marram grass traps moist air into its leaves, collecting water through the hair-like structures and moving it throughout the plant through the xylem vessels (green). Using a microscope technique called incident fluorescence with ultraviolet excitation, this image distinguishes between the xylem vessels and sugar-carrying phloem (blue) to reveal the grass's delicate, yet eerie internal structure.

LAKES OF METAL WASTE

Flying over the Australian outback, you might glance down and see what appears to be a fiery orange lake. However, this dam isn't holding back waters erupting from hell, but the waste product produced from aluminium extraction. Known as bauxite tailings, or more commonly as 'red mud', it involves dumping the iron-rich waste into dams, which creates vast orange lakes. More than 160 million tonnes are produced each year, and with that comes concerns over the waste's environmental impact. Containing toxic chemical compounds, the surrounding soil is at risk of damage from these chemicals leaching out and rendering it infertile.

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HISTORY

Salvagers can now open the Titanic to take its 'voice'

Words by **Brandon Specktor**

A federal judge has given a salvage company permission to cut open the hull of the RMS Titanic in order to retrieve the ship's famed Marconi wireless telegraph machine. The telegraph machine, sometimes called 'the voice of the Titanic', is notorious for sending out the ship's final distress messages on 14 and 15 April 1912 after the ship hit an iceberg in the North Atlantic and started to sink, ultimately killing some 1,500 people. The equipment sits within three adjoining rooms known as the Marconi suite, located on the ship's topmost deck, and has long intrigued salvagers at RMS Titanic, Inc., a for-profit company that won the rights to salvage the Titanic and exhibit its artefacts in 1994.

Retrieving the telegraph might require cutting open the ship's hull with a remotely operated vehicle (ROV), the company said, but a court ruling in 2000 prohibited them from doing so. That ruling also prohibited the company from removing anything directly from the wreck – on later expeditions the company removed thousands of artefacts from a debris field near the ship. Now, 20 years later, the company has successfully challenged that ruling, citing concerns that the room and its contents could be destroyed by deterioration if not recovered soon. "The boat is sort of degrading… right at the Marconi suite," Bretton Hunchak, president of RMS Titanic, Inc., said. "Our main concern is that it is going to be lost very soon."

Rebecca Beach Smith, a federal judge in Virginia, ruled that "the Marconi device has significant historical, educational, scientific and cultural value as the device used to make distress calls while the Titanic was sinking". That, coupled with the deterioration, is enough to justify its removal, even if that requires "limited cutting" of the ship's hull, Smith ruled.

Some organisations, including the National Oceanic and Atmospheric Administration (NOAA) oppose this sort of invasive shipwreck surgery. In February NOAA lawyers expressed concerns that RMS Titanic, Inc. will use this ruling as a 'placeholder' to gain greater access to the ship and its artefacts on future expeditions. The

© Getty

A proposal to cut the Titanic's telegraph machine free of the shipwreck was just approved in federal court

shipwreck is protected as an archaeological site according to an international agreement between the US, the UK, Canada and France, an agreement that the company's proposed expedition flatly violates, the lawyers said.

For now the court ruling only grants permission for 'minimal' cutting with the express purpose of recovering the Marconi telegraph. If possible the RMS Titanic, Inc. team will enter and exit the Marconi suite through existing holes in the ceiling, Hunchak said, but this may not be possible. The company's expedition to remove the telegraph could begin as early as August or September 2020 if the state of the coronavirus pandemic allows them to operate safely, Hunchak said.

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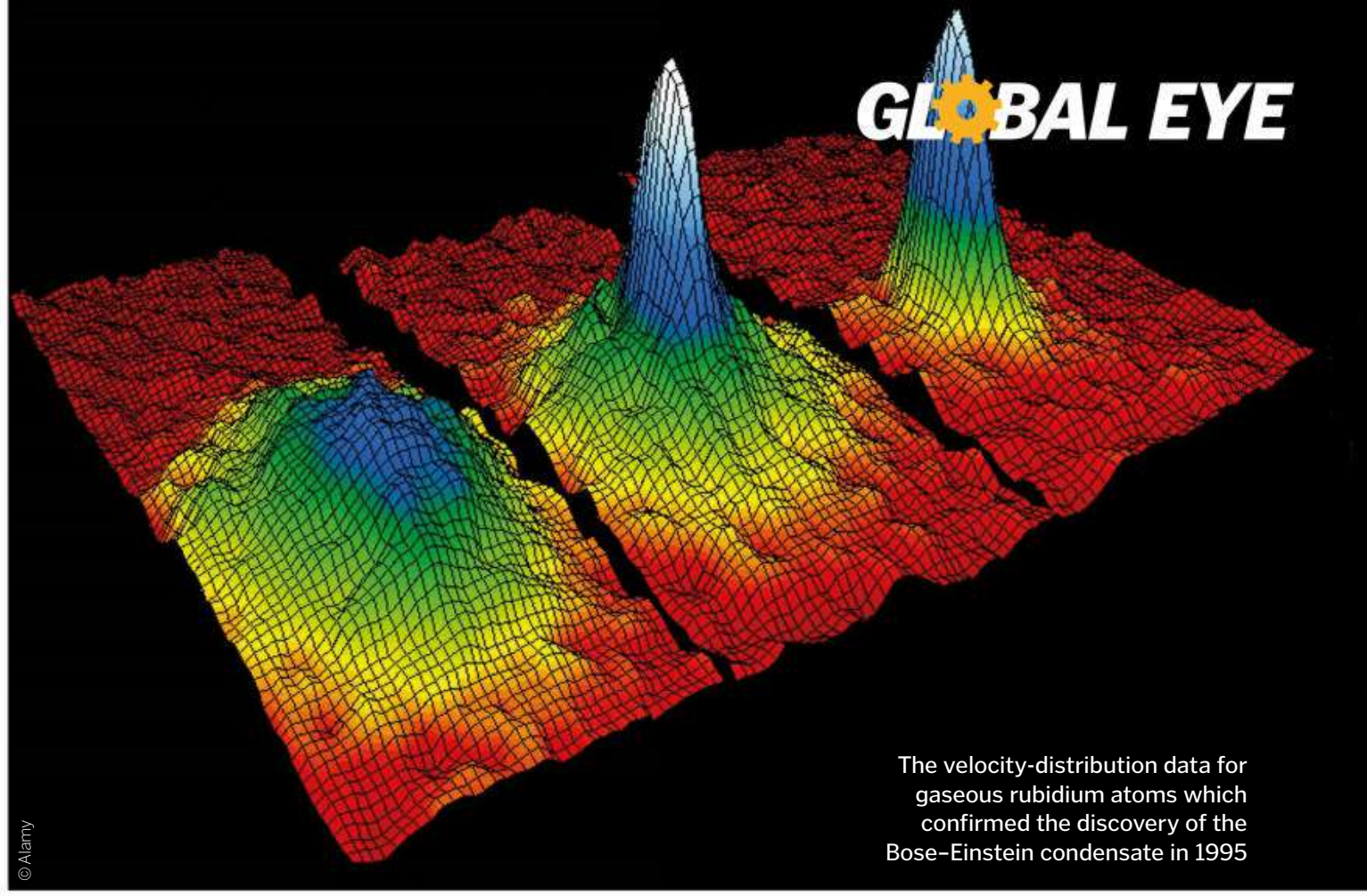

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The velocity-distribution data for gaseous rubidium atoms which confirmed the discovery of the Bose–Einstein condensate in 1995

SPACE

Exotic fifth state of matter created on the space station

Words by **Charles Q. Choi**

Scientists have generated an exotic form of matter in the unique microgravity environment aboard the International Space Station (ISS) and are using it to explore the quantum world.

There are four states of matter common in everyday life: gases, liquids, solids and plasmas. However, there is also a fifth state of matter, Bose-Einstein condensates (BECs), which scientists first created in the lab 25 years ago. When a group of atoms is cooled to near absolute zero the atoms begin to clump together, behaving as if they were one big 'super-atom'.

Bose-Einstein condensates straddle the boundary between the everyday world, governed by classical physics, and the microscopic world, which follows the rules of quantum mechanics. In the world of quantum mechanics a particle can behave as if it were spinning in two opposite directions at the same time, or as if it existed in two or more locations simultaneously. Because they follow some of these quantum behaviours, Bose-Einstein condensates may offer scientists key clues into the workings of quantum mechanics, potentially helping to solve mysteries such as how to create a 'theory of everything' that could explain the workings of the cosmos from the smallest to largest scales.

> *"Atoms begin to clump together, behaving as if they were one big 'super-atom'"*

Scientists now routinely create Bose-Einstein condensates in hundreds of labs across the world. However, one limitation that stands in the way of this research is gravity. These 'super-atoms' are extraordinarily fragile and the set-ups used to create them are incredibly delicate, so the pull of gravity felt on Earth can disrupt both, making it challenging to learn much about them.

As such, researchers developed the Cold Atom Laboratory (CAL), which can generate Bose-Einstein condensates in the microgravity found in orbit aboard the ISS. Launched in 2018, the Cold Atom Lab is small and requires only a relatively small amount of energy, so it meets the specific constraints aboard the space station. While the equipment originally needed to create Bose-Einstein condensates on Earth can take up an entire lab, the Cold Atom Lab takes up only about 0.4 cubic metres and altogether requires an average of 510 watts of power.

Using the Cold Atom Lab, researchers in a new study found that they could increase the amount of time they can analyse these condensates after the traps confining the material are switched off to more than one second. In comparison, here on Earth scientists would only have hundredths of a second for the same task.

"In the past our major insights into the inner workings of nature have come from particle accelerators and astronomical observatories; in the future I believe precision measurements using cold atoms will play an increasingly important role," said CAL project scientist Dr Robert Thompson.

SPACE

Mars once had rings and a bigger moon

Words by **Rafi Letzter**

Mars' satellites may cycle back and forth between rings and moons

Mars may have once had a giant ring that eventually got smooshed to form one of its oddly shaped moons, new research suggests. Mars has two small, lumpy moons: Phobos and Deimos. Phobos orbits closer to the Red Planet and follows the line of Mars' equator. Deimos orbits farther away along an orbit that's tilted by two degrees off the plane of the Martian equator. The wonky orbit adds evidence to the idea that Phobos may once have been a giant ring that eventually coalesced into its present shape.

In 2017 a team of researchers argued in *Nature Geoscience* that the Martian moons go through cycles, ripped apart into thin rings by the planet's gravity, then eventually forming moons again. In each cycle the moon formed from the ring is smaller than its former self, with bits of the rings falling out of orbit and drifting out into space. Over billions of years, generations of moons would have gone through these cycles of ring-moon-ring, scientists suspect.

Now, in a recent study, a team of researchers has showed that an ancient Martian moon, 20 times the size of Phobos, could have jostled Deimos into its current orbit. "The fact that Deimos' orbit is not exactly in plane with Mars' equator was considered unimportant, and nobody cared to try to explain it," said research scientist Matija Ćuk. "But once we had a big new idea and we looked at it with new eyes, Deimos' orbital tilt revealed its big secret." Two moons that follow similar paths around a planet can end up in a situation called 'orbital resonance' where one bobs up and down around the other's orbit.

Here's what the scientists think happened in this ring-moon cycle to explain the current Mars set-up: Deimos formed billions of years ago, and ever since it has sort of just been overlooking the dynamic ring-moon party. Over that same time, a giant ring encircling Mars got squished into a moon, or moons, dispersed back into a ring and then into a moon again, and so on. During one of these iterations, one of the moons – the giant mystery moon – knocked Deimos into its current ring, and then just like that this mystery moon vanished into its ring form. A remnant of that ring, the scientists suspect, formed Phobos, which is the younger of the two Martian satellites.

In order for this theory to work the long-lost moon that formed out of a Martian ring would have needed to start moving away from Mars and into a resonance with Deimos that would have produced the more distant moon's current angled orbit.

Eventually part of the ring-moon cycle will repeat again. The younger moon Phobos is losing altitude over Mars, and researchers expect that it will eventually break up and form a disintegrating ring around the planet. That will leave little Deimos orbiting alone, with only its lopsided orbit as a record of what else used to exist around Mars.

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ANIMALS

Bumblebees bite plants to help them bloom

Words by **Nicoletta Lanese**

When their pollen supply runs short, bumblebees bore tiny semicircle-shaped holes in the leaves of flowering plants, causing blooms to appear weeks ahead of schedule. Bee-bitten plants bear flowers about two weeks to a month sooner than untouched plants, according to a new study. Researchers attempted to recreate these bee-bite patterns using metal forceps and a razor, but even then the damage inflicted by bees boosted flower production more effectively than the scientists could; bee-bitten plants bloomed eight to 25 days before the artificially damaged ones did, depending on the plant species.

In early experiments, buff-tailed bumblebees (*Bombus terrestris*) appeared to ramp up this biting behaviour when deprived of pollen, a key food source for both bee larvae and the worker bees themselves. To test the hypothesis the research team deprived one group of worker bees of pollen for three days, while a different group was provided with abundant pollen resources. When released into enclosures full of flowerless tomato and black mustard plants, the deprived bees began nibbling at the leaves with gusto. The satiated group, in contrast, inflicted only minor amounts of leaf damage.

To confirm that the hungry bees weren't simply eating the leaves, or carrying bits back to their hive, the authors placed paper cones beneath the plants to catch falling debris. Leaf bits accumulated in the cones, and no leaf residue appeared back at the hive, they noted. The bee-inflicted damage resembles tiny half-moons – carved by the insects' mandibles – or pinprick holes poked out with their proboscises, their tubular mouthparts.

The team observed this biting behaviour in both their laboratory bees and wild colonies. In the wild bees the team noted that biting behaviour dropped off once the outdoor plants began to flower, bolstering the idea that the bees damage leaves when their available pollen supply runs low.

While several species of wild bumblebees, including *B. terrestris* and *B. lucorum*, ravaged the flowerless foliage, honeybees and common furry bees that visited the roof would not. But why would only bumblebees beat up plants to boost their flower supply? That the scientists don't know yet.

If cues from bees can accelerate flowering, "scientists might realise a horticulturist's dream by deciphering the molecular pathways through which flowering can be accelerated by a full month," said Lars Chittka, a professor of sensory and behavioural ecology at the Queen Mary University of London.

Some plant species flower early in response to drought, but few studies have explored how animal behaviours might prompt plants to bloom

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GLOBAL EYE

© Contains modified Copernicus Sentinel data (2020), processed by ESA

An oil spill in the Arctic Circle. Oil is shown in red travelling in the Ambarnaya River

PLANET EARTH

Satellites spot major oil spill in the Arctic Circle

Words by **Chelsea Gohd**

Two European satellites have spotted a catastrophic oil spill in the Arctic Circle. About 20,000 tonnes of diesel oil has leaked into a river in the Arctic Circle after a fuel tank at a power plant near the Siberian city of Norilsk collapsed at the end of May. The Russian Investigative Committee has launched an investigation into the incident, as the plant reportedly waited for two days before informing authorities about the spill.

As you can see above, the oil travelled down the Ambarnaya River on 31 May and 1 June. The river flows into Lake Pyasino, which feeds into the Pyasina River. Watching from space, the European Space Agency's Copernicus Sentinel-2 mission has observed the spill, for which Russia has declared a state of emergency.

The spill has contaminated a swath of land that covers roughly 350 square kilometres. It is believed that ground subsidence – the sinking or settling of the ground – beneath storage tanks holding fuel at the plant is behind this spill. This incident comes during a time when unusually high temperatures are causing the Arctic permafrost to melt.

Copernicus Sentinel-2 is an ESA mission made up of two satellites circling Earth in a Sun-synchronous orbit. The satellites monitor and take high-resolution images of Earth's surface. They contribute important data to the European Union's Copernicus program, which focuses on issues including climate change, land monitoring and emergency management.

STRANGE NEWS

Underwater ‘ghost town’ could reappear next year

Words by **Brandon Specktor**

A medieval ‘ghost town’ may soon emerge from the bottom of a lake in Tuscany. It could be the first time that the ruined village has seen the light of day in more than 25 years. This Italian Atlantis is known as Fabbriche di Careggine, a 12th-century town that was once home to about 150 residents, 31 houses and a stout stone church. In 1946 it met its end when Italian energy company Enel built a hydroelectric dam in the surrounding valley. The inhabitants were moved to a nearby village, Fabbriche di Careggine was flooded and the new artificial Lake Vagli was born.

In the 75 years that the town has sat on the lake’s bottom, curious visitors have had four chances to walk among its ancient, water-weathered stones – in 1958, 1974, 1983 and 1994 – when Lake Vagli was drained for dam maintenance, and it may soon be drained again.

The Enel energy company recently mentioned that it was beginning to discuss a potential lake draining with local municipalities, both as an opportunity to clean the Lake Vagli reservoir and to boost tourism in the area.

As you might suspect, the exciting prospect of visiting a medieval ghost town briefly resurrected from the mighty deep has drawn considerable crowds over the years. During the several months that Lake Vagli was drained in 1994, roughly 1 million tourists visited the resurfaced Fabbriche di Careggine.

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The sunken village of Fabbriche di Careggine, Tuscany, could make a rare reappearance in 2021

The angle at which the asteroid hit Earth 66 million years ago played a large role in the demise of the dinosaurs

© Getty

PLANET EARTH

Dinosaur-destroying meteor struck at ‘deadliest possible’ angle

Words by **Mindy Weisberger**

The flaming space rock that slammed into Earth and wiped out the dinosaurs struck at the worst possible angle, new research suggests. Colliding with an enormous, fast-moving cosmic projectile would have been disastrous under just about any circumstances, but it also hit the planet at a steep angle, causing the deadliest possible outcome by releasing much more gas and pulverised rock than it would have with a shallower approach.

Scientists modelled the path of the meteor as it hurtled towards Earth, creating the first 3D simulations to trace the event from start to finish. The asteroid closed in on its target from the northeast and struck at an angle of about 60 degrees above the horizon.

That crash was around 66 million years ago, ending the Mesozoic Era with a bang. The event triggered global climate change and led to mass extinction, wiping out 75 per cent of all life on Earth, including all non-avian dinosaurs. A scar from the impact remains to this day as a massive circular basin underneath Mexico’s Yucatán Peninsula, known as the Chicxulub crater and measuring around 200 kilometres wide.

In the researchers’ simulations they modelled an asteroid measuring about 17 kilometres in diameter, travelling at approximately 43,200 kilometres per hour and with a density of 2,630 kilograms per cubic metre.

They also examined asymmetrical structures in the crater at subsurface depths of nearly 30 kilometres to visualise the direction and angle of the asteroid as it struck. Though previous studies have modelled the crater’s appearance at the moment of impact, this is the first time that researchers have used deeper structural data to model the crater during the impact’s later stages, as it shifted and settled into its final shape. Working backwards from this formation gave the scientists a more accurate view of the asteroid’s approach.

Compared with most other impact angles, ejecta from such an impact would have produced ‘the worst-case scenario’ for the planet, spewing up to three times as much sulphur and carbon dioxide into the atmosphere as other impact angles did, the models showed.

This steep-angled trajectory “was among the worst-case scenarios for the lethality on impact,” said lead study author Gareth Collins. “It put more hazardous debris into the upper atmosphere and scattered it everywhere – the very thing that led to a nuclear winter.”

SPACE

Scientists create mini-supernova shock waves

Words by **Chelsea Gohd**

Researchers have created a miniature version of supernova shock waves in a lab here on Earth to solve a long-standing cosmic mystery. When stars die and explode in supernovae, they create shock waves. These powerful shock waves blast out cosmic rays, or highly energetic particles, into the universe. The waves act almost like particle accelerators, pushing these particles out so fast that they approach the speed of light. However, scientists have yet to fully understand exactly how and why the shock waves accelerate these particles.

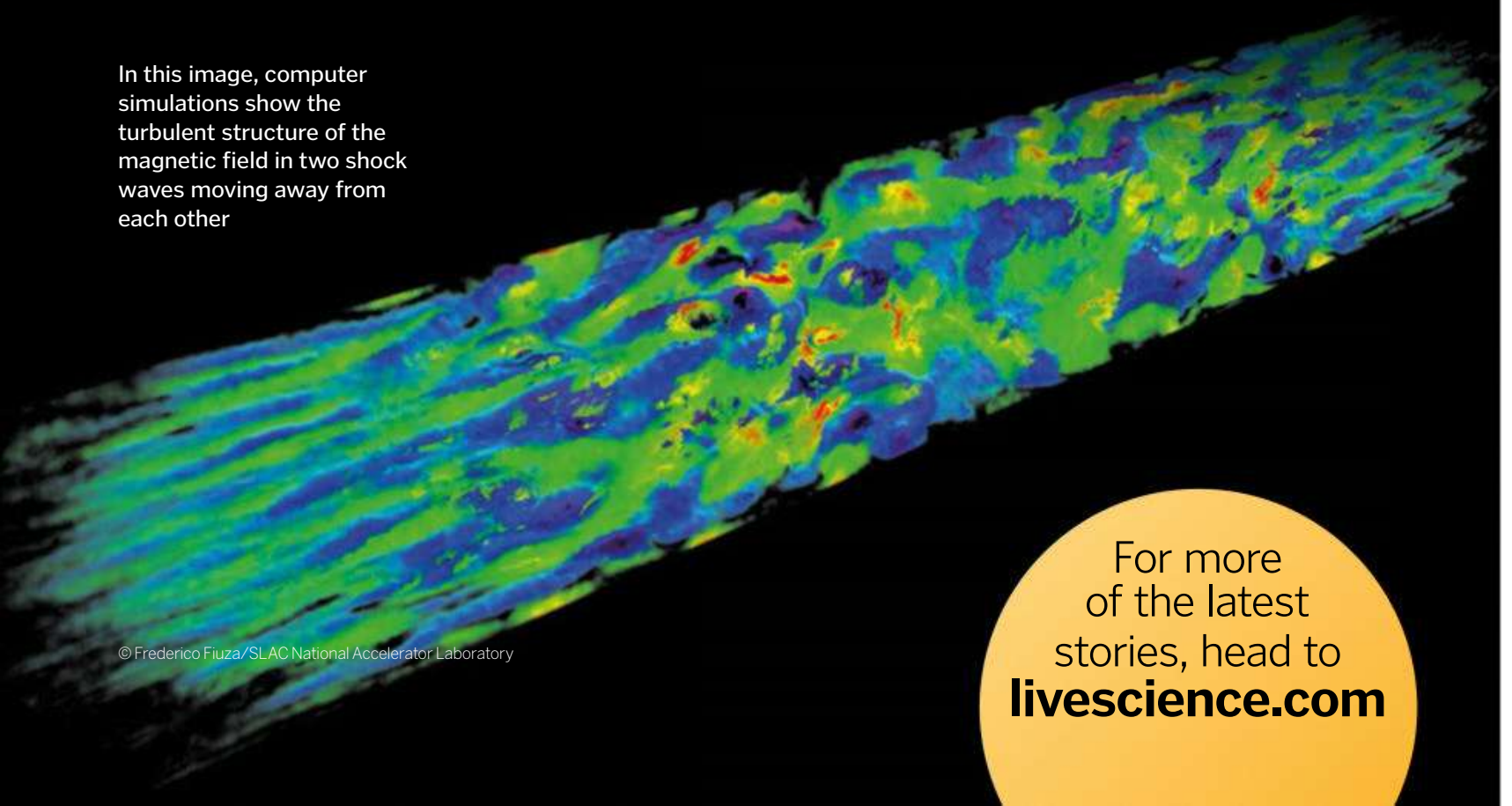
"These are fascinating systems, but because they are so far away it's hard to study them," said Frederico Fiuza, who led the new study. To better study these cosmic shock waves, scientists brought them to Earth. Well, not literally, but researchers have created a scaled-down version of supernova remnants. "We are not trying to make supernova remnants in the lab, but we can learn more about the physics of astrophysical shocks there and validate models," Fiuza said.

Fiuza and his colleagues worked to create a fast, diffuse shock wave that could mimic the shocks that follow a supernova. The scientists worked at the National Ignition Facility, a Department of Energy facility at the Lawrence Livermore National Laboratory in California. They shot powerful lasers at carbon sheets to create two plasma flows, targeted at each other. When the plasma flows collided, they created a shock wave "in conditions similar to a supernova remnant shock". The scientists observed the experiment using both optical and X-ray technology.

By studying a miniature analogue of the cosmic phenomenon here on Earth, the researchers verified that the shock was capable of accelerating electrons to nearly the speed of light. However, the mystery of exactly how these electrons reached such speeds remains, which prompted the scientists to turn to computer modelling. "We can't see the details of how particles get their energy even in the experiments, let alone in astrophysical observations, and this is where the simulations really come into play," says co-author Anna Grassi.

While the cosmic mystery of the shock wave-accelerated particles remains, computer models created by Grassi revealed one possible solution. According to these models, turbulent electromagnetic fields within the shock wave could accelerate electrons to the speeds observed.

Fiuza, Grassi and their colleagues will continue to investigate the X-rays emitted by the accelerated electrons and hone their computer simulations, according to a statement. Other future research will study positively charged protons blasted by the shock wave in addition to the electrons studied in this work.



In this image, computer simulations show the turbulent structure of the magnetic field in two shock waves moving away from each other

© Frederico Fiuza/SLAC National Accelerator Laboratory

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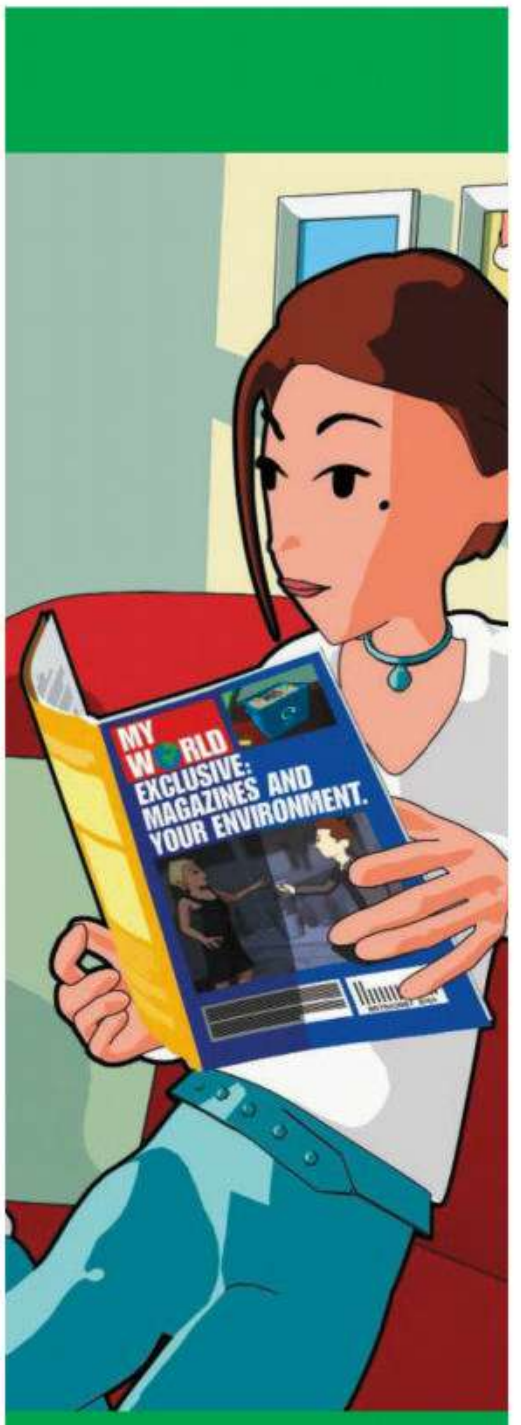

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■ Price: **£214.99 / $199.99**
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Take your office on the road with this wireless battery-powered portable printer by Canon. This compact printer is a great addition to any home office, and thanks to its built-in rechargeable battery can print up to 330 pages on a single charge for those coffee shop work sessions. The PIXMA also boasts WiFi connectivity to print straight from your smartphone, but if you find yourself without internet access it is also equipped with a direct connection to fit to your devices.

© Canon

© AIRBAR

AirBar

■ Price: **$59.99 (approx. £47.70)**
www.air.bar

Transform your laptop into a touchscreen device with the AirBar. Compatible with Windows 10 notebooks and Apple MacBooks, the AirBar connects to your laptop magnetically without the need for installation. The AirBar allows you to completely change the way your computers works, such as scrolling through documents, flipping through browsers and pinching to zoom in, all without touching your trackpad.

© Nanoleaf

Nanoleaf light panels

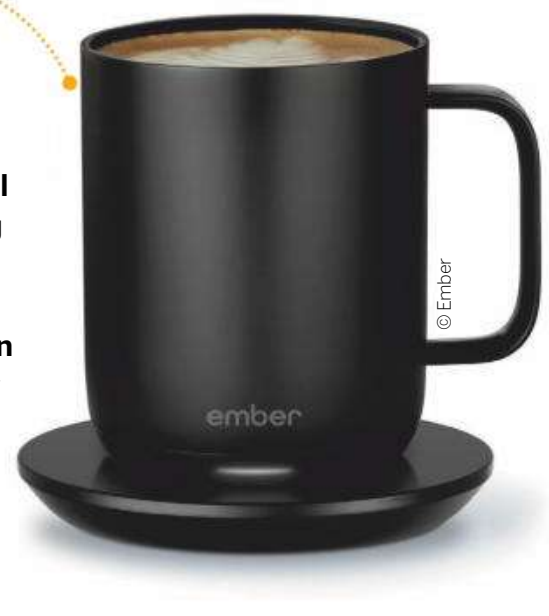
Price: **from £179 / $199.99**
www.nanoleaf.me

Brighten up your home office with these high-tech lighting panels by Nanoleaf. Using the companion app, this interactive light system allows you to change the colour of each panel at the touch of a button or select one of the pre-programmed themes. Nanoleaf is compatible with other smart home devices such as Alexa and Google Home for voice-activated control.

Ember Mug²

Price: **£99.95 / $99.95** www.ember.com

We've all made a cup of tea or coffee, sat down to work and 20 minutes later realised that we haven't taken a sip of the now-cold beverage. With the Ember Mug², reaching for your drink will never again leave you disappointed thanks to its built-in heating system. Using the companion app, set your personal temperature preference so this high-tech mug can maintain it for up to 1.5 hours. Easy to clean and submersible up to one metre, this mug is a great addition to your home office.



© Ember

Evolve2 65

Price: **£169 / $239**
www.jabra.co.uk

Block out the noise of a busy household with these sound-cancelling headphones by Jabra. The Evolve2 65 not only offer great sound quality for listening to your favourite music, but with their comfortable design and professional microphone, taking work calls is a breeze. These wireless headphones are Bluetooth enabled and boast a battery life of around 37 hours with a single charge.

© Jabra

APPS & TOOLS

Clockify

Developer: **COING Inc.**

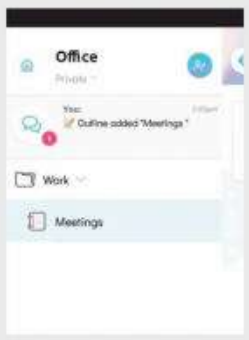
Price: **Free / Google Play / App Store**

Keep track of your workday with this timer. Schedule your day, then hit the timer to see how long you've been working on certain jobs or tasks.

Simplish

Developer: **52 Spring LLC**

Price: **Free / Google Play / App Store**



If you really love making lists, then this is the app for you. Organise your projects, meetings and to-do lists using this easy-to-follow app.

Stay Focused

Developer: **Innoxapps**

Price: **Free / Google Play / App Store**

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Find Stay Focused on next screen
Stay Focused
Off
Click it and turn on the switch like below
Permit usage access
Watch Video Tutorial

This app helps keep you from being distracted by non-work-related apps by offering temporarily restricted access while you work.

Zoom

Developer: **Zoom**

Price: **Free / Google Play / App Store**

Carry out conference calls, team meetings or even virtual pub quizzes for up to 100 people with this easy-to-use video chat app.

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SPECIFICATION

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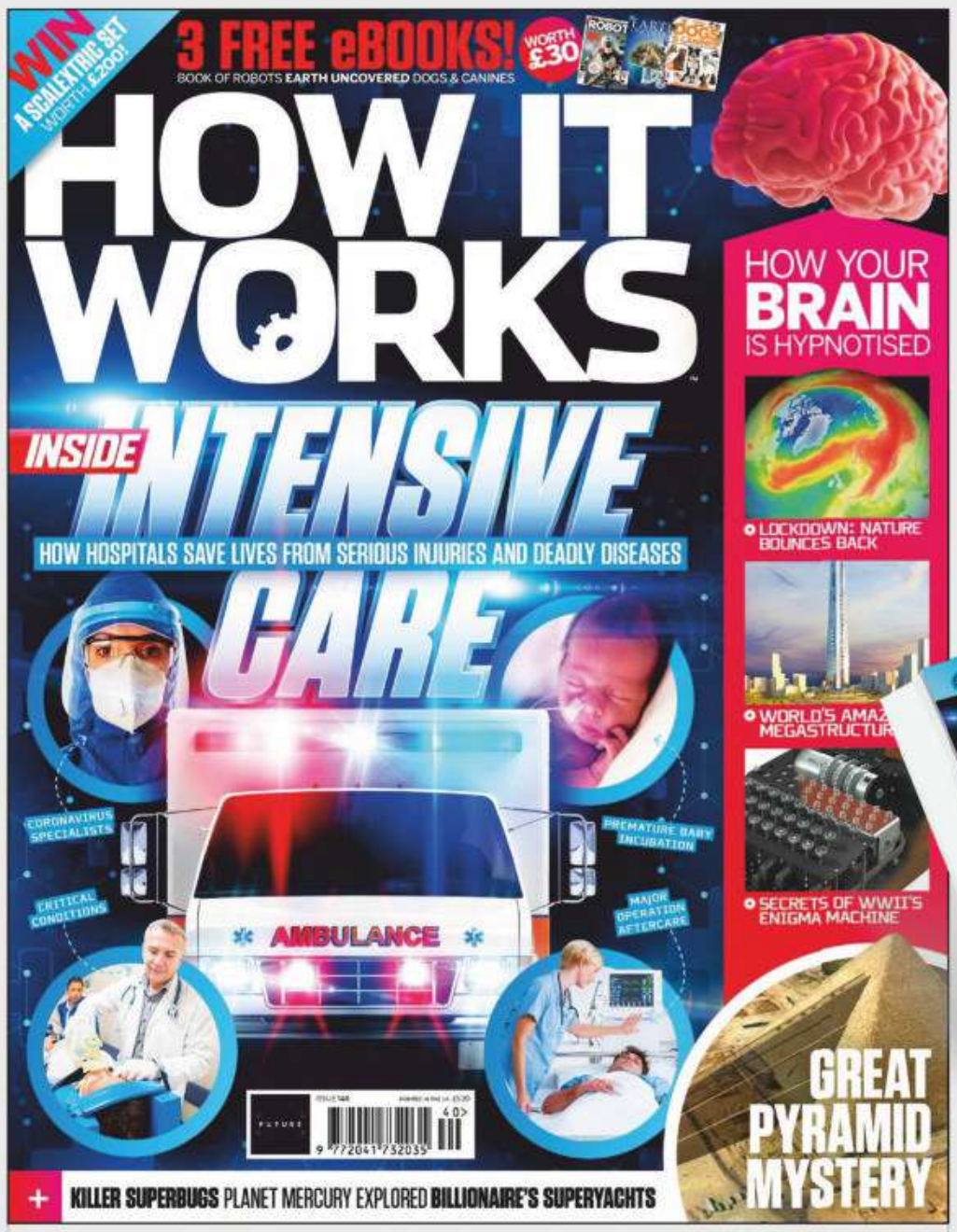
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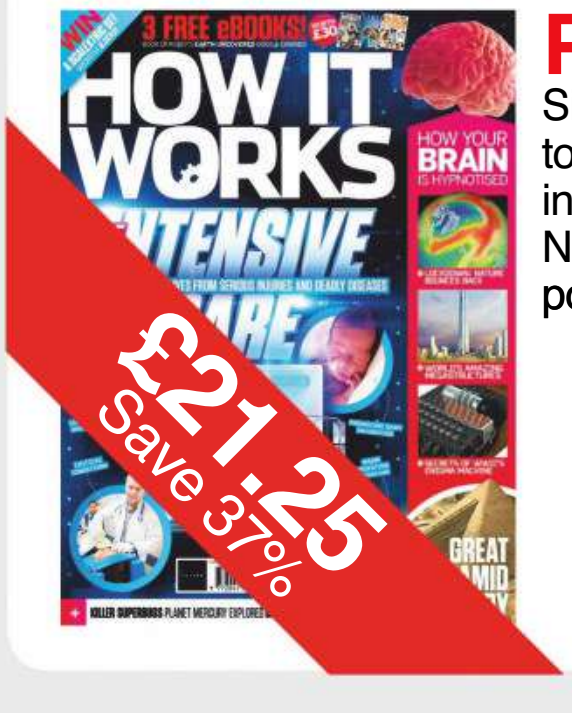

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INSIDE INTENSIVE

WHEN THE LINE BETWEEN LIFE AND DEATH BECOMES DANGEROUSLY FINE, HOW DO THE PEOPLE AND MACHINES IN HOSPITALS AID YOUR BODY'S BATTLE?

Words by **Ailsa Harvey**

CARE

How long would we last without healthcare? What would we do without a number to call when we are reminded how fragile life can be, or a place to go with the confidence that we will receive the best possible care from a team of professionals who know our bodies inside out? While every area of a hospital has the improvement of health at its core, there is one department that elevates the emotion, urgency and stakes of every action to a much greater level. This is the intensive care unit (ICU).

Intensive care units, otherwise known as critical care units, are special wards within hospitals where patients with life-threatening conditions can be monitored and treated. People who qualify for ICU admittance are those whose conditions are unstable. They need to be monitored constantly to ensure that any changes are noticed and acted upon before irreversible damage is done.

It's a place nobody outside of the medical profession wishes to find themselves. Whether you are the patient yourself, relying on the tubes and machines that are taking on the role of your organs, or a visitor who can only sit at a bedside and hope that your loved one will pull through, the ICU is an undoubtedly gruelling environment. To an onlooker, the turn of every corner can overload the senses. The chaotic combination of mechanical beeps, frantic alarms and intense bedside operations are in stark contrast to the people lying still on their beds in occasional periods of eerie silence. Who knows what the next few seconds will bring?

For the various patients occupying these high-priority beds, the cause of their admission

Consultant doctors work with their team to draw conclusions about every patient

© Getty

Ten per cent of babies are born prematurely

© Getty

BEDSIDE TECH

When organs fail to stabilise life, patients are wired up to these computers to assist with bodily functions

Electrodes
For the EEG monitor to work, it needs to be connected to the brain. The best way to do this is through electrodes. Metal discs with multiple thin wires are attached to the scalp. The wires pick up any electrical activity in the brain and the information is transferred to the monitor.

Bedside monitor
Displaying some of the body's vital functions, such as heart rate, blood pressure, temperature and oxygen levels, this screen is connected to multiple devices. Equipped with alarms, if any function reaches dangerous levels, medical staff are instantly alerted.

Ventilator
This breathing machine helps the lungs to inhale and exhale air. A tight mask can be fitted to cover the mouth and nose. In more severe cases the patient needs to be sedated to insert the tube into their windpipe through their neck.

Central line
A thin, soft plastic tube called a catheter is inserted into a large vein. This entry to the bloodstream can be used to apply a dose of medicine or draw blood for testing.

1:2
On average, there is one nurse for every two level 2 patients in an ICU.

Electroencephalogram (EEG)
Recording electrical activity in the brain, this machine can visually display changes in brain function. Unusual recordings can help pinpoint causes of seizures or memory loss.

Dialysis machine
In cases of kidney failure, a machine can be attached to a large vein, often in the neck. Blood leaves the body through a tube and into the machine, which acts as a filter to remove harmful waste products from the blood. The filtered blood is then returned into the patient's body.

Pulse oximeter
To measure oxygen levels in the blood, this tool clips onto the end of the patient's finger. As wavelengths of light are passed through the finger, the device displays the body's pulse rate as well as oxygen levels.

© Illustration by Nicholas Forder

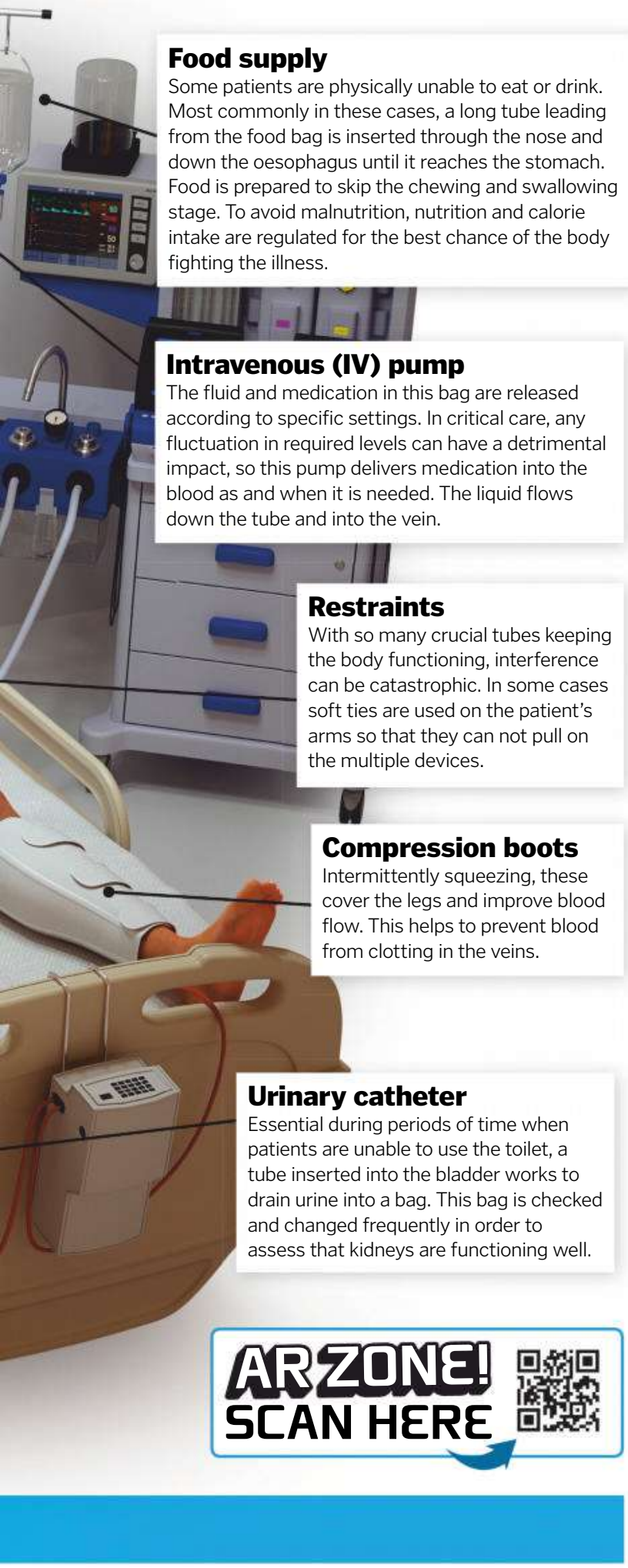
may be just as unexpected, while others might have been anticipating it, having experienced their bodies' slow decline. Critical care follows for a range of reasons: some come straight from the operating room after undergoing major surgery; some are escorted there from the scene of an accident who may have severe burns, broken bones or organ failure and some are monitored after a serious short-term condition such as a heart attack or stroke.

To work on these specialised wards requires a combination of qualities. Called 'intensivists', these medical staff demonstrate an ability to adapt within a workplace where conditions are continuously changing. They need to be able to help with every case that enters through the doors and have the ability to continue performing at the highest level regardless of whether the other battles surrounding them have been victorious or not. These marvellous medics are not only specialised in intensive care, but also have their own area of expertise to put their specific knowledge and skill set to use. To be a specialist you need to be the best of the best, and this is something that is of utmost importance in an environment where anything less could cost someone their life.

170,000
The number of hospital beds in the UK.

Most of us hope death is far in the future, but the reality is that nothing is guaranteed. Life is full of unexpected complications. Inside the ICU, those who are at their weakest now have a better chance of recovery than at any previous time in history. This is due to innovative life-saving technology.

As knowledge of how the human body functions has grown, we've developed machines that have increased in effectiveness, mimicking every function of each human organ when the corresponding organ in a patient is failing. While it's impossible to be in two places at once, electronic sensory



Food supply
Some patients are physically unable to eat or drink. Most commonly in these cases, a long tube leading from the food bag is inserted through the nose and down the oesophagus until it reaches the stomach. Food is prepared to skip the chewing and swallowing stage. To avoid malnutrition, nutrition and calorie intake are regulated for the best chance of the body fighting the illness.

Intravenous (IV) pump
The fluid and medication in this bag are released according to specific settings. In critical care, any fluctuation in required levels can have a detrimental impact, so this pump delivers medication into the blood as and when it is needed. The liquid flows down the tube and into the vein.

Restraints
With so many crucial tubes keeping the body functioning, interference can be catastrophic. In some cases soft ties are used on the patient's arms so that they can not pull on the multiple devices.

Compression boots
Intermittently squeezing, these cover the legs and improve blood flow. This helps to prevent blood from clotting in the veins.

Urinary catheter
Essential during periods of time when patients are unable to use the toilet, a tube inserted into the bladder works to drain urine into a bag. This bag is checked and changed frequently in order to assess that kidneys are functioning well.

AR ZONE! SCAN HERE

systems are better armed with the intelligence to respond to changes in a patient's condition and alert staff to their bedside with alarm systems. Bedside technology is working together with the human intellect that comes with years of training. And machines can use imaging to provide a quick and clear insight into the internal functions beneath our skin, allowing staff to better decide their next step in treatment.

With experience, intensivists will have seen most cases that enter the ICU before. They know the protocol and are equipped with the tools to give patients the best chance of recovery. This applies to any disease and injury that causes the body's functions to fail, but what happens when the ICU sees a new case?

This has become the reality recently, with the COVID-19 pandemic putting immense strain on these wards. It's important to remember that while global focus has been on this virus, the ICU continues to see the same range of illnesses it has always had to accommodate for on top of the influx of added patients. While the world was faced with many unanswered questions as people began showing up to hospitals with the new, severe respiratory disease, the medics and their technology were able to see where the body was suffering straight away and provide breathing support through ventilators. This shows that the core principles of care in the ICU remain the same, regardless of the cause.

The intensive care that is provided around the clock in these special wards has been brought into the limelight during recent times, but as global health crises come and go, the ICU never rests. Nobody is immortal, but this ever-improving system is in place to throw every effort into the healing process. Whatever the reason is, every day the ICU sees a diverse mix of talents and technologies all fighting for one thing: a second chance at life.

Dependency levels
This gradation groups patients based on the severity of their conditions

LEVEL 0

General assistance

Patients at this level are looked after through normal ward care. Patients may need an IV or oxygen using a face mask. They can remain for over four hours without needing to be assisted.

LEVEL 1

Additional support

At this level additional clinical support is required. These patients are at risk of deteriorating or were previously at higher levels of care and are attended to at least every four hours.

LEVEL 2

Organ failure

Level 2 conditions include a single failing organ and those who are at high risk of further complications – such as those having recently undergone a major operation. With likelihood of deterioration in mind, patients are checked hourly or more.

LEVEL 3

Multiple organ failure

At the top level of monitoring, these people have the highest risk of death. To ensure this is prevented as much as possible, in each situation multiple specific machines aim to provide each body's needs.

THE IMPACT OF COVID-19

Throughout the beginning of 2020, the coronavirus pandemic amplified the high pressure put on staff in intensive care units. Usually in these wards a range of critical illnesses are seen. However, with such a surge of COVID-19 cases, wards dedicated to this one virus have been opened.

Most people in these wards need ventilators to survive, and everyone treating patients needs gear to protect them from being infected and ending up in the beds themselves. Hospitals around the world have witnessed strain on these facilities, including limitations in the personal protective equipment (PPE) needed to continue working safely.

One of the most heartbreaking struggles in these tailored wards is the lack of contact with the outside world. While visiting family and friends often make up a substantial percentage of people in the ICU, no visitors are allowed in COVID wards. These unsettling times mean survival is the only way to see loved ones again. For others it has meant having to hear of lives lost with no chance to say their goodbyes.

"Everyone treating patients needs gear to protect them"

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NHS Nightingale Hospital London was built in nine days for the intensive care of COVID-19 patients

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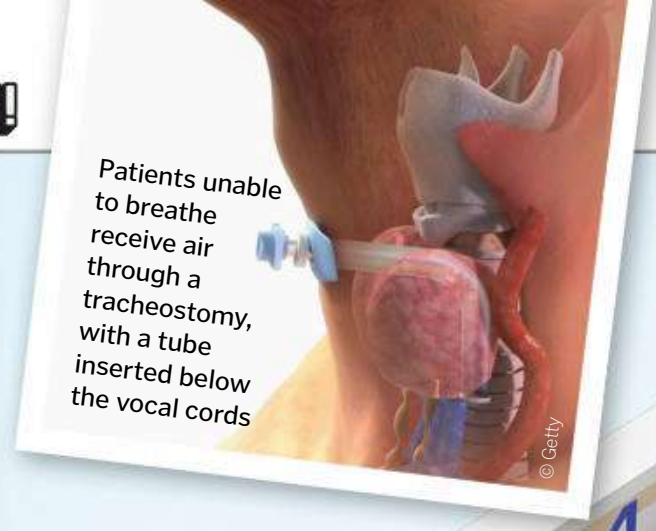
Bedside monitors can display information about the blood, heart and brain at the same time

70%
Nearly three-quarters of ICU beds are used by adults.



Patients unable to breathe receive air through a tracheostomy, with a tube inserted below the vocal cords

© Getty

Physiotherapists
Lying horizontally, unable to move for a prolonged period of time and with a body in its weakest condition, patients can lose immense strength and mobility. These specialists stop joints from becoming stiff and help to exercise patients' muscles, but this is not the extent of the help. With many suffering from breathing difficulties, they assist patients with their breathing by strengthening their chest and lungs.

Nurses
When doctors have prescribed the relevant drugs and fluids, nurses are needed to make sure the recommended levels are given and that they are done so correctly. Taking care of a couple of patients at a time, they know how best to care for those in a critical condition and can create a relationship of trust with their patients, putting them at ease through some of the scariest times.

Doctors
The team of doctors in an intensive care unit cover all areas of expertise. This team is led by an ICU consultant who is responsible for overseeing the progress of patients every day and advising the next steps in treatment.

Pharmacists
Seeing patients alongside doctors and nurses, pharmacists can give additional advice on medications. As experts in how medicines should be supplied and applied, they can make sure medication is taken appropriately and intercept any errors before they show negative effects.

Occupational therapists
There is more to intensive care than simply staying alive. The ward is a patient's home for a select period of time, and where possible they often want to gain back small levels of independence. Occupational therapists provide the best solutions to ensure that while they are being treated a patient's daily activities can be carried out to the best of their ability, optimising their mental health as well as physical.

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Speech and language therapists
Speech therapists can improve patients' abilities to speak and swallow during their time in the ward, and in cases where the individual has suffered a brain injury can help improve their affected speech for the future. When tracheostomies are required, which involves making a hole in the patient's throat to insert a breathing apparatus, speech therapists can be of invaluable assistance, ensuring that there will be no unnecessary impact to speech and swallowing as a result.

Dietitians
Incorporating the right foods into your diet is important for even the healthiest individual, but when teetering on the edge of life and death, the body relies on the best nutrition to support recovery. Dietitians monitor food intake and individual responses to ensure patients are being fed the correct volumes and consistencies with the best nutritional value. Choosing the best nourishment is a big responsibility at a time when sick patients have no control over what is put in their bodies.

MEET THE SPECIALISTS

Like heroes of the hospital, each member has mastered a particular superpower

Social workers
The outcome of each medical case often lacks certainty. During their time inside the ward, families and loved ones sometimes need as much support as those on the beds, just in a different way. Social workers provide emotional support to families and visitors at most hospitals, helping them to understand the situation through counselling or helping with financial issues.

In one of the most unnerving sections of a hospital, it is common for visitors and patients to be filled with worry and uncertainty. However, the professionals need to work with quite the opposite emotions, informing those they are caring for, acting decisively and using their expert skills to improve their patients' wellbeing. Each member of the diverse team carries a specialised essential role, but their main objectives are consistent: for patients and loved ones to leave the hospital healthier, happier and, most importantly, alive.

Q&A LEADING AN ICU TEAM

Dr James Bromilow is the lead consultant for intensive care at Poole Hospital in England. With 12 years' experience in this role, he tells us about the unpredictability each day can bring

WHAT IS A DAY IN THE ICU LIKE?

The day is split between looking after patients who are already admitted to the ICU and assessing those on other wards who might need admitting. We can get called to all sorts at any time, from a nine-day-old baby to a 99 year old, from someone with a heart problem to a road traffic accident – it's unpredictable. Patients come to us at all times of the day or night. Every day is different and every day represents different challenges for us.

HOW MUCH DOES A VARIED TEAM OF SPECIALISTS HELP?

Generally intensive care doctors are quite good at dealing with problems with most parts of the body, but when we have a particular specialist problem, we ask our colleagues in other areas to see the patients and help us with their management. Second opinions and further advice can make sure that what we're doing is right.

HOW HAS POOLE HOSPITAL'S ICU COPED DURING THE COVID-19 PANDEMIC?

At the beginning we just didn't know how big the surge of patients was going to be, and we didn't know when that surge was going to come. We didn't know how to treat patients with COVID because we had never seen that before. COVID behaves slightly differently to other viruses with similar reactions, so we had to learn quickly. We were lucky that our surge came two or three weeks after London's. We got information on a daily basis of how the doctors and nurses were treating these patients and that informed the way that we did things. PPE kept our staff very safe. We got low in stocks in the early phases, but thankfully never ran out.

WHAT'S THE MOST CHALLENGING ASPECT OF THE JOB?

Sometimes you have to accept that a patient isn't going to get better, despite your best efforts and treatments. We often have difficult conversations with patients and their loved ones to tell them that the patients aren't going to get better. Then we have to prioritise treating their symptoms, making sure we give them a dignified end to their life. It's a big responsibility, but something we've trained for for many years. It took me 18 years from starting medical school to becoming a consultant. It's never a responsibility that we take lightly. Equally, it can be the most rewarding job when people come in very sick, and within a matter of hours, days or weeks you can get them through their really critical stage and onto the road to recovery. It can be a very gratifying job.

SPECIALISED UNITS

From treating injuries on the road to newborns battling for their lives, how can care be tailored to specific needs?

NEONATAL ICU

Some of the weakest patients also happen to be the smallest

The first few days as a new parent can be some of the most intimidating yet remarkable times. However, in the neonatal intensive care unit, fear and dread come in much heavier doses. When babies are born, they no longer rely solely on their mother. Their bodies have to sustain themselves, but sometimes complications mean they are not able to do this.

In their own ICU exclusively for babies, they are supported by machines until they are hopefully strong enough to be discharged. Some of the most common reasons babies are taken into intensive care include premature births where the baby isn't yet fully developed, low sugar or oxygen levels, breathing problems or infections. The latter is the most common cause of death.

Incubator
Babies are placed in these clear boxes to keep them warm, as when they are sick or premature their temperature often drops. Holes in the side allow staff to adjust equipment, and sometimes parents can have contact with their newborn.

X-ray tray
In modern incubators the X-ray receptor is built into the tray beneath the baby. This picks up the X-ray image. These are often needed to check the location of tubes embedded and to look for signs of lung and bowel issues.

Temperature and humidity controls
Some baby boxes have closed tops, which makes it easier to control the temperature and humidity levels. This can be done using this keypad, which constantly displays conditions inside. A probe on the skin can also change settings automatically as the baby's body temperature fluctuates.

MOBILE ICU

The first responders supplying intensive care on the go

Time is often of the essence when ambulances are called. When someone has been in a severe accident or their health has drastically deteriorated, a life-supporting hospital bed is sometimes just a step too far away. In these cases an advanced care ambulance is sent. This is essentially an ICU on wheels. When the call comes in the severity of the situation is assessed, and if deemed necessary a mobile ICU is deployed. Staff on these vehicles have the most training and are able to fit drips, supply medication and keep the patient functioning during the drive to hospital.

Treatment kits
This ICU has its own portable technology. Like you would find in the hospital, the ambulance has systems that can provide oxygen through ventilators and drips to be filled when the condition is assessed. Other treatment kits are stored securely for travel. These cater for any situation the team are faced with when they arrive at the scene. Usually included are burn and wound kits, surgical tools, medication, a tracheal kit for inserting airway apparatus and equipment for monitoring blood pressure, temperature and other bodily functions.

Stretcher support
While travelling at high speed towards a hospital, the bed needs to be fixed to the floor and wall. This stops the patient moving about and dislodging life-saving devices.

Stretcher
The temporary bed is on wheels so that it can be transported to where the critically ill person is. Unable to move, they will be lifted onto the stretcher and taken to the ambulance.

Monitor
Ambulance staff need a visual aid to show them whether the treatment they are giving the patient is working and keeping them stable until hospital staff can take over.

Staff seats
When the patient is stable, the paramedic will sit here as they check systems for changes and deterioration.

INFECTIOUS DISEASE WARDS

What personal protective equipment can be worn when battling invisible illnesses?

When a patient is admitted to intensive care with an infectious disease, precautions need to be taken to stop this single case spreading. As part of their duty of care, medical staff need to be hands-on to treat patients, but how do you maintain this duty when a simple touch could make you just as critically ill?

Patients who are known to be infectious are often put in isolation. This is a room with all the equipment of the beds in the main ward, but with surrounding walls keeping the infection from spreading. Signs on the door inform staff of the patient's condition, and before entering they are required to wear protective equipment so that they can limit the risk of endangering their own lives as they save others. In cases of a pandemic like the coronavirus, full wards can be dedicated to one common disease.

© Shutterstock

Vital signs monitor
This machine displays electrical signals from the baby's heart so that hospital staff can easily spot changes. Wires run from the baby's chest to this monitor to relay electrical signals of the heartbeat and breathing rate.

Ventilator
Helping them to breathe, air flows through tubes into their airways. These can be extremely fast puffs which creates a scary sight for the parents as their baby's body moves violently. However, these fast pumps help make sure the tiny air passages in their lungs stay open.

Water tank
Water in this tank is used to humidify the air around the baby. This is essential in premature babies as the outer layer of their skin has not fully formed. Water leaves their body through their skin at a greater rate, and being in humid conditions helps them to retain more.

Hairnet
This piece of equipment prevents hair from contamination, as well as keeping it compact. If hair is loose it increases the likelihood of face-touching.

Surgical mask
This fluid-resistant material is hooked onto the ears to keep it in place, covering the nose and mouth. They catch any bacteria or viruses found in liquid droplets, but do not work effectively against airborne microorganisms as these particles are much smaller.

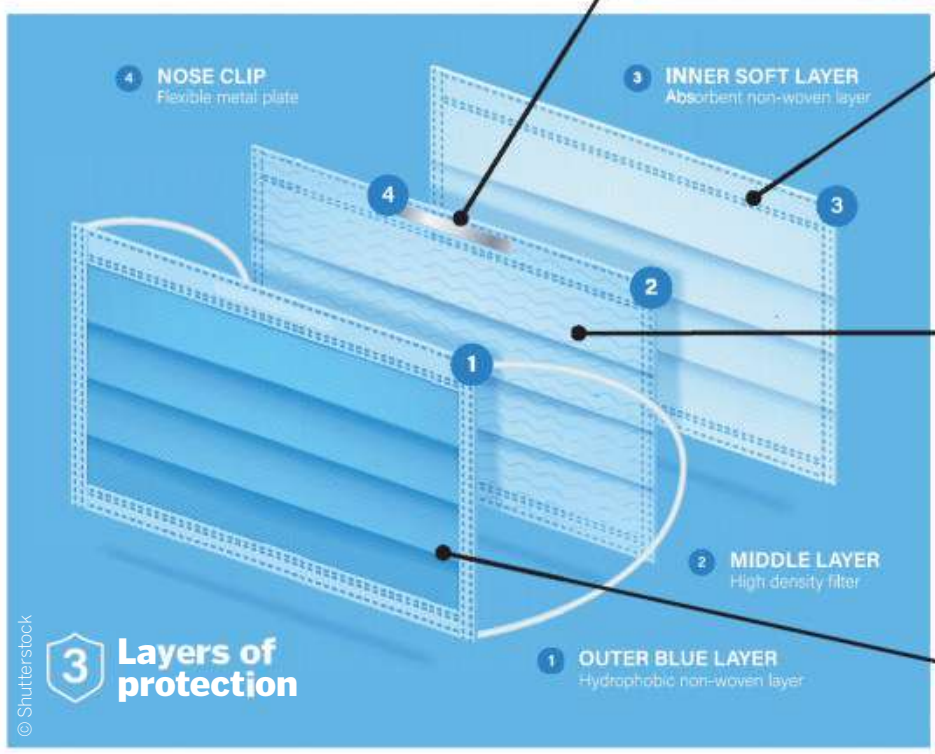
Nose clip
A piece of aluminium bends to fit the face mask around the bridge of the nose. This prevents any gaps between the mask and the face.

Soft layer
For comfort this layer is soft, absorbing any sweat and spit released during long working hours.

Full-face shield
Providing a better coverage of the face than nose and mouth masks, these plastic coverings are attached using an adjustable band around the head. This shields the face from any airborne disease.

Long-sleeved gown
Disposable full-length gowns catch any sprays and spillages. Upon leaving the ward they are removed, leaving the clothes underneath unscathed and clean.

Gloves
Hands are often most responsible for carrying and spreading disease. Gloves are an essential when examining infected patients and are frequently binned and replaced.



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Filter layer
As the middle material, this sheet is a two-way barrier against germs. Stopping tiny particles from travelling through the mask both ways, the dense material works to trap germs.

Outer layer
The outer layer is hydrophobic, meaning it repels water. As the first layer of defence, it is instant protection from any fluids that come into contact with the face.

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SUPER STRUCTURES

Discover the engineering tech behind humankind's biggest buildings as we track the rise and rise of the skyscraper

The statistics

Jeddah Tower

Height: 1,000+ metres (planned)

Floor count: 200

Building use: Apartments and offices

Construction dates: 2013 to present

Architect: Adrian Smith

Area: 530,000 square metres

Eventual status: Tallest building in the world

© Adrian Smith & Gordon Gill Architecture; SPL

Today these Goliaths are often seen as symbols of national and civic pride, as well as being a key solution to urban overcrowding. Yet the skyscraper as we know it only came into being in the late-19th century, not through the ambition of architects but through a combination of contemporary engineering techniques and materials that finally triumphed over the builder's age-old enemy: gravity.

For most of history the tallest human-made structure on Earth was the Great Pyramid of Giza at 147 metres – a height that would barely qualify as a skyscraper today. The reason was simple. Because all buildings were constructed from bricks and mortar, they were all built to the same principle: the higher the building, the bigger the base. However, all that changed with the Industrial Revolution and the ability to construct ever stronger and longer iron and steel girders. Suddenly buildings could be taller without having to take up so much space at ground level, sparking an international race that culminated in today's tallest and most talked-about buildings.

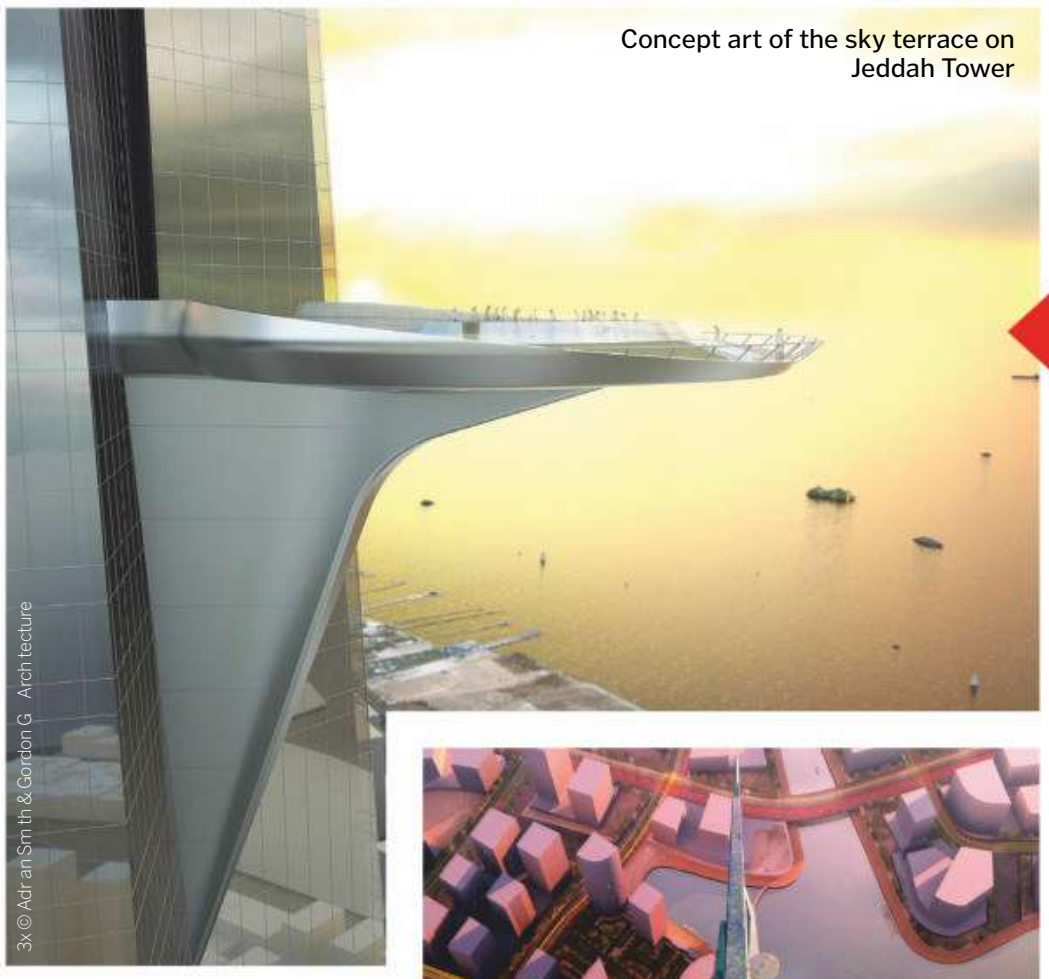
Skyscrapers are a monumental challenge to both design and construction. Winds can cause them to sway, earthquakes can shake even the strongest foundations and fires can melt through steel cores. As skyscrapers begin to approach the edges of thinner, colder air, living conditions must be adapted to compensate. For all these reasons, building skyscrapers remains a constant test of human ingenuity against natural forces.

Designing a skyscraper requires the combined efforts of hundreds of skilled professionals and thousands more to construct, usually to strict deadlines. It starts with planning, these days involving lengthy computer-aided design processes that must factor in everything from ground conditions and load and stress testing, health and safety guidelines and emergency evacuation procedures.

Once construction begins, attention focuses around a steel skeleton called the superstructure – a collection of vertical columns and horizontal girders that run through the building. This concentrates the downward force of gravity into a relatively small area at the base, transferred through the substructure – a series of steel columns, plates and springs underpinned by reinforced concrete – that extends far underground. This allows the building's concrete and glass exterior, or curtain wall, to reach higher by effectively only having to support its own weight. Ultimately, however, the whole structure rests on clay, making the foundation just as important as the visible structure that rises above it into the clouds.

It is the superstructure that has to cope with the most strain. For the first skyscrapers – which rarely exceeded ten storeys – iron was used, but throughout the 20th century when the US ruled the world of high-rise construction, steel became the material of choice. Superstructures used to resemble a series of steel boxes containing both horizontal and vertical supports throughout to spread the load. However, as skyscrapers grew taller, the distance between these supports decreased, reducing available floor space – a vital consideration – as well as increasing weight. In the mid-1960s a new tubular design emerged based around interconnected exterior columns, reducing the number of interior columns required. It was this design that enabled the original World Trade Center and other record-beating structures to be made.

For nearly 150 years modern skyscrapers have been built to inspire shock and awe, relying on eye-catching designs and ever-higher altitudes to attract tenants, businesses and visitors. In technical terms there is no real



Concept art of the sky terrace on Jeddah Tower

3x © Adrian Smith & Gordon G Architecture

Even the drop-off area of Jeddah Tower has received great attention to detail from architect Adrian Smith + Gordon Gill Architecture

Kingdom of the skies

Standing at over 1,000 metres high – though the actual final height of the tower still remains a closely guarded secret – Jeddah Tower will be nearly twice as tall as the US' Willis Tower and at least 170 metres higher than the world's current leader: the United Arab Emirates' Burj Khalifa.

Construction began in April 2013 after long delays and heated debate. Earmarked for offices and luxury apartments, some questioned who exactly will be able to afford to live in the tower. Nearly one third of the Burj Khalifa (29 per cent) is unoccupiable, while other high-profile Middle Eastern developments such as Dubai's artificial archipelago complex, The World Islands, were viewed as little more than follies at the time of their construction, during a period of economic downturn.

Then again, skyscraper design has always been as much about prestige as practicality – and there's a competitive edge. Three buildings have been called 'world's tallest' in the past 30 years – at an average cost of $1.6 billion – yet all have attracted significant interest and publicity for their host cities. The project's backers remain confident that Jeddah Tower will transform Jeddah's reputation as a cultural and economic centre, much as the Petronas Towers did for Kuala Lumpur, Malaysia. However, a completion date isn't set.

The Burj Khalifa – currently the world's tallest building – took about six years to construct

reason why skyscrapers couldn't reach three or even five kilometres, and with commercial airliners cruising above eight kilometres they'd have little to fear from accidental collision – although since 9/11 the public has understandably less confidence in such assurances.

Indeed, it is the threat of terrorism that poses the biggest obstacle to the continued dominance of the skyscraper. Ever since the twin towers of the World Trade Center in New York collapsed from the top down and inside out, architects have been forced to go back to the drawing board about how skyscrapers should be designed and the kind of events they should be built to withstand. Nowhere has this been felt more keenly than in the One World Trade Center, which opened on the Ground Zero site in November 2014. Featuring not only a 56-metre windowless concrete base but also 0.9-metre reinforced concrete walls for stairwells and elevator shafts, windows made of blast-resistant plastic on one side of the building, dedicated stairwells for firefighters and a ventilation system including biological and chemical filters, safety and security now lie at the heart of this highly symbolic megastructure.

With the continuing risks involved in containing so many people in a single exposed building, as well as the escalating costs of building them, will future generations still idolise the skyscraper or is this just a new challenge to our 4,000-year obsession with 'growing up'? Only time will tell...

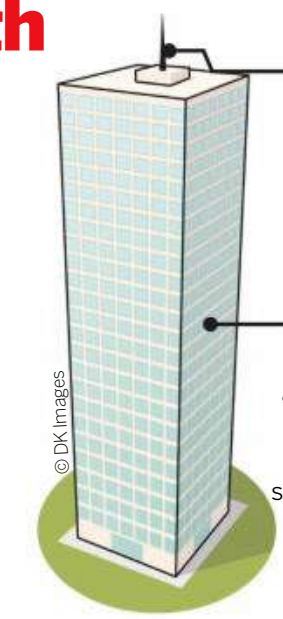
The design of the One World Trade Center is highly focused on safety and security

On solid ground

Long before a skyscraper takes shape, the foundation has to be planned and excavated. First the ground must be surveyed, taking into account not just its composition but also the likelihood of earthquakes, which can be compensated for by installing seismic dampers. A pit is then dug, which can extend up to five floors, into which vertical piles or reinforcing rods are sunk, securing the substructure into the bedrock. Typically this substructure is made up of vertical columns resting on cast-iron plates which sit on top of a grillage of horizontal steel beams. The substructure spreads out like a pyramid below the ground, distributing the enormous weight, and is encased in concrete. Only once the foundation and substructure are complete can the superstructure be lifted and secured onto it, allowing the rest of the construction to begin.

Strength from within

What elements make up the core of a skyscraper?



Spire
An essential design element and therefore counted in the building's official height – as opposed to antennae, which are not.

Windows
External window panels are lowered into place as each floor is completed. They are made from super-toughened glass or, on occasion, blast-resistant plastic.

Beams and girders
Lattices of steel beams and girders give the superstructure strength, often covered with plaster, vermiculite and fibreglass to add corrosion and heat protection.

Curtain wall
With the superstructure bearing most of the load, the curtain wall of reinforced concrete and fire-resistant plaster mainly supports its own weight.

Ground floor
The skyscraper's heart, not least because of its reinforced stairways and elevators, as well as the building's safety and security systems.

Elevators
Banks of elevators rise through the core of the building, making it fit for purpose. Scenic elevators may run along the exterior wall.

Grillage
A framework of steel beams and girders providing a broad, strong and rigid core to the substructure.

Columns
Secured to the grillage by metal plates, steel columns rise through the skyscraper's core and perimeter.

Bedrock
The layer of solid rock far beneath the surface soil, onto which the building must be secured by steel piles riveted to iron plates.

Concrete
Alongside steel, reinforced concrete is the backbone of the skyscraper, not least to provide a solid, level base for construction to begin.

Top of the world

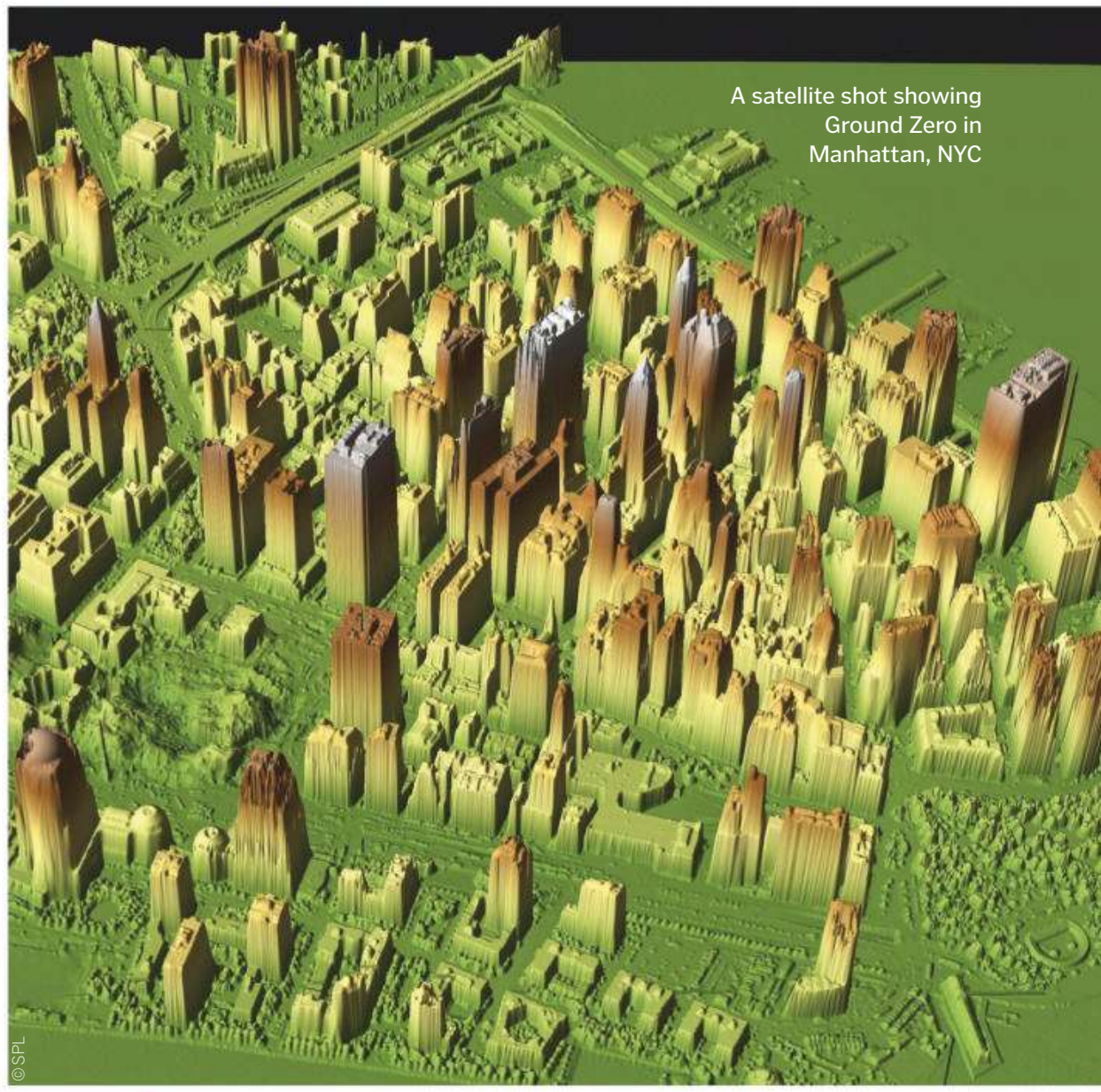
2x © Skidmore, Owings & Merrill LLP/dbox

Material matters

Advances in skyscraper design and construction have always gone hand in hand with improvements in construction materials, particularly the two key components of steel and concrete.

Concrete must be reinforced by pouring it onto a grid of steel rods, although smart fibres may also be contained within, as well as carbon nanotubes – among the strongest materials known to humankind – to withstand the half-million tonne or so weight of materials and people resting on them. Meanwhile, concrete walls and internal skeletons have become progressively lighter, stronger and more fire resistant. Chilled, pressurised pumping procedures are also used to propel concrete to greater heights before setting.

Even more important was the evolution of modern steel production and fabrication that made skyscrapers possible in the first place. From Englishman Henry Bessemer's process for mass-producing steel in the 19th century to Fazlur Khan's tubular steel superstructures that first enabled heights of over 500 metres to be reached, state-of-the-art steel remains the backbone of the modern skyscraper to this day.



A satellite shot showing Ground Zero in Manhattan, NYC

© SPL

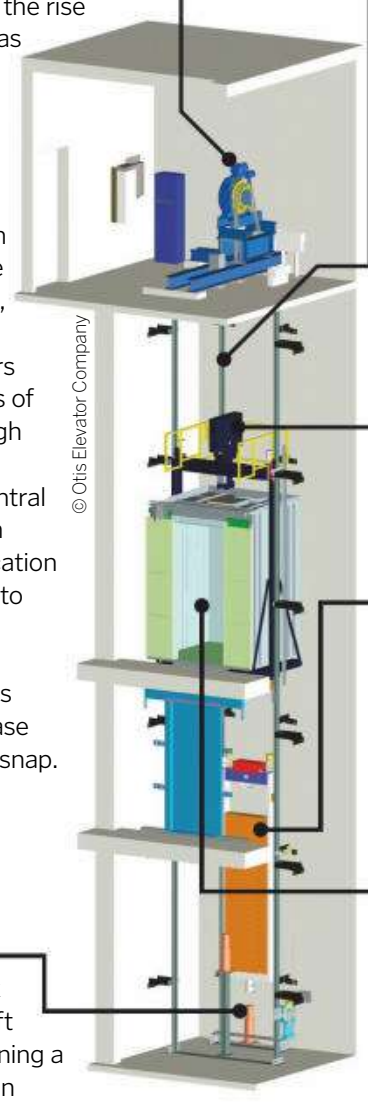
Where to find the planet's tallest skyscrapers

	PING AN FINANCE CENTRE	LOTTE WORLD TOWER	ONE WORLD TRADE CENTRE	GUANGZHOU CTF FINANCE CENTRE	TIANJIN CTF FINANCE CENTRE	CHINA ZUN	TAIPEI 101
	4	5	6	7	8	9	10
	599 metres	554.5 metres	541.3 metres	530 metres	530 metres	528 metres	508 metres
	Shenzhen, China	Seoul, South Korea	New York City, United States	Guangzhou, China	Tianjin, China	Beijing, China	Taipei, Taiwan

Elevators

How do the lift systems in super-tall structures work?

A key contributor to the rise of the skyscraper was the elevator. Elisha Otis invented the first safety elevator in 1852, featuring a mechanism to prevent the car from crashing down if the cable broke. Normal, freight, express and even scenic elevators run through all areas of skyscrapers, although still focused on the highly reinforced central shafts. They contain two-way communication and safety systems to control speed, load capacity and door openings – as well as multiple cables in case one or more should snap. Without lifts, life for office workers and residents would be almost impossible.



© Otis Elevator Company

Winch
Part of a motorised control mechanism situated above each elevator, responsible for raising and lowering the compartment. May or may not contain gears.

Rope
A traction steel cable capable of supporting the weight of a full compartment and counterweight. Typically skyscraper elevators use four to eight ropes each.

Governor
A system of ropes, sheaves and pulleys connected to the compartment and shaft base ensuring the elevator moves at a controlled pace.

Counterweight
Reduces the load carried by the winches and motors. Counterweights and compartments run on guide rails to reduce speed should the rope snap.

Compartment
Capable of carrying around 12 people at about 2.5 metres per second. It features sophisticated weight, speed and temperature sensors.

Buffer
A heavy-duty shock absorber at the shaft base, usually containing a piston mounted in an oil-filled cylinder.

Landmine robots

How do these machines navigate terrain riddled with explosives?

Words by **Ailsa Harvey**

Army members can control demining robots from a control unit, equipped with viewing screens and controllers

What makes landmines so difficult to detect is that they were designed not to be. Built as a hidden military weapon and used to defend land and target opponents as they step or drive onto the earth above, the destruction and danger was all part of the plan.

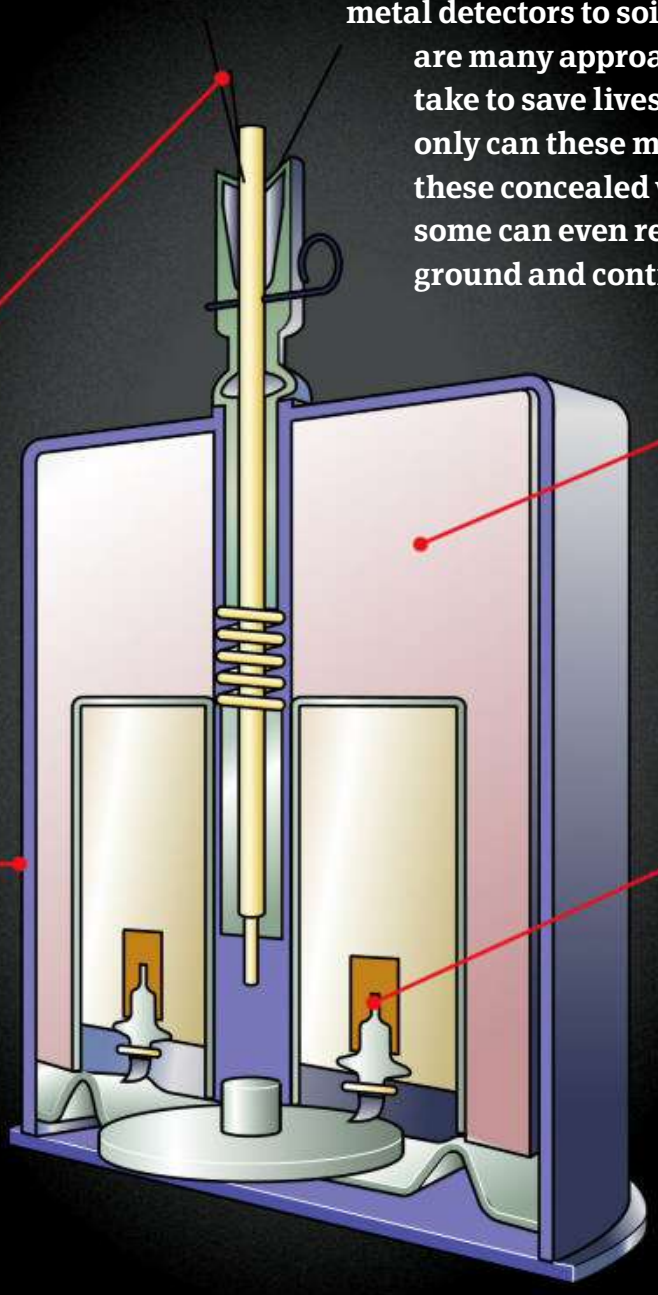
To prevent death and injury in current or past war zones, these underground explosives need to be safely detected. How can a soldier progress with confidence when every step is a gamble? The most common technique for demining is manual, involving people putting their lives at risk as they slowly parade the landscape, eyes to the floor.

Those who take on this role are risking their own lives with every step. Around the world, groups are looking for faster and safer ways to make the land beneath them safe again. This is where robots are given a job. Engineered specifically for the task, hardy machines can be controlled from a distance to search the ground below.

From the tiny wheelers to the large beasts scanning masses of land, these helpers have multiple tricks under their armour. From metal detectors to soil-analysing waves, there are many approaches that robots can take to save lives from landmines. Not only can these mechanical militants find these concealed weapons, once detected, some can even remove them from the ground and control their detonation.

Under the shell

What are these demining machines looking out for?



Pressure prongs
These prongs reach towards the surface above to detect pressure. Connected to the central rod, pressure applied to these prongs creates contact with the fuse. Robots need to work around these sensors to detach the fuse before it can trigger the detonator.

Fragmentation shell
The shells of landmines used to be made of metal, but many are now made of plastic with very small volumes of metal. This is to limit the methods robots and other machines can use to find them.

Main charge
This section is full of explosive chemicals. The machines try to prevent this from being ignited by the fuse, as it will set off a deadly reaction. Chemical sensors can often be used to detect explosives in the ground.

Metal fuse
Landmine robots often rely on metal detection to locate landmines. In modern landmines only parts of the fuse encased deep within the device are made of metal. Metal-detecting methods can no longer be fully relied on.

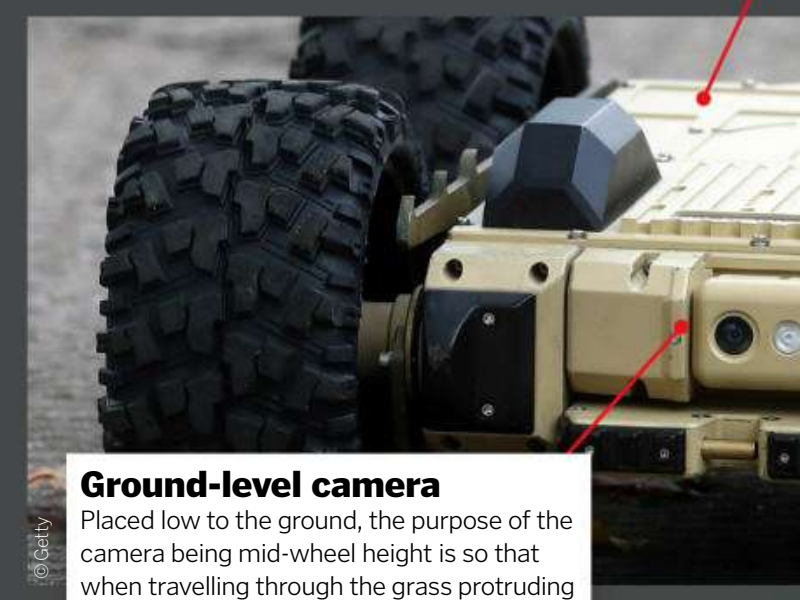
Controlled remotely
The Scorpion can operate at distances up to 2,990 metres away from the person controlling it.

Rods
This pair of rods at the back help the bot to move up stairs by hooking onto them.

Scorpion

Believed to have entered production at the beginning of this year, Scorpion may look like little more than a small remote-control car, but the beauty of this robot is its ability to be built and adapted.

Adding a plow for moving the soil and rods that can climb stairs, the potential of Scorpion lies in how you equip it. A key advantage of this is that when performing a role, such as demining, it remains compact. Only the required features need to be added. When it comes to landmines, its method is to carry its own charges. These small devices can be left near landmines and set off when the robot is at a safe distance. Scorpion plows into the ground and leaves the explosive to detonate the landmine.



Ground-level camera
Placed low to the ground, the purpose of the camera being mid-wheel height is so that when travelling through the grass protruding features can be easily spotted.

SPECS
Speed: **13kph**
Weight: **18kg**
Technique: **Flipping**

Radio antenna
This antenna picks up communication from the remote control, allowing movements to be determined and cameras to be accessed from afar.

Batteries
The robot runs on lithium-ion batteries, which are chosen for their high energy density. PackBots can last between four and eight hours.

Cameras
The camera attached to the front allows those controlling the robot to see its surroundings through a wide-angle lens. Another one on the arm, facing towards the grabber, is a close-up camera which is able to show details of the hazardous landmine.

Flippers
Pointed flippers can aid manoeuvres by lifting the device at one side. They can grip onto obstacles and prevent limitations in the search.

Gripper
The arm is controlled to grab landmines with the grippers at the end. This applies pressure to the device, separating the fuse. Without a fuse, the danger is removed. The gripper is also equipped with cable cutters.

© Getty

PackBot
The PackBot is one of the military's smaller robots, used to neutralise landmines and other explosive devices. Being small in size, it is compact, easy to transport and has the additional benefit of being quick to deploy.

This robot has been engineered to withstand rough treatment, which certainly comes in handy on a battlefield. Testing shows it is able to fall 1.8 metres onto concrete and continue working. After such an accident the PackBot can use its treaded flippers to turn itself back into an upright position. This appendage is ideal for any rough environment and for conquering obstacles.

Battery
With its built-in power supply this compact robot can carry out its landmine searches for around four hours at a time.

TALON 3B
As a bomb-disposal robot with widespread use throughout the US military, the TALON is a larger and stronger machine. Its long arm is able to lift objects of nine kilograms and can be used for a range of missions, with its robust structure keeping it intact. One of the tasks it has perfected is the clearing up of dangerous war remnants, making it a strong contender for demining.

SPECS
Speed: **8.37kph**
Weight: **45kg**
Technique: **Strength**

Arm
Has a 360-degree rotating wrist which increases the dexterity of the gripper and enables care to be taken when handling explosives.

Cameras
The device can be mounted with up to seven cameras. These include all-weather, night-vision and thermal cameras which can assist in spotting landmines.

Technology range
Depending on the mission, different sensors and features can be attached to the robot. These include chemical, radiation, gas and temperature sensors.

Rechargeable batteries
This robot uses two lead acid batteries, giving it a three-hour run time before a recharge.

Manoeuvrability
The robot's tread can climb stairs up to 43 degrees and navigate through rock and rubble.

© Alamy

Four-wheeled
Without the tracks seen in other robots, its movement may be limited in treacherous terrain. However, the four separate wheels give it the advantage of a higher speed.

COMET-IV
The main difference in the COMET series is the use of legs over wheels or tracks. When put to use the complex mechanism shows greater balance over uneven terrain, but it lacks some of the faster speeds found in other demining robots. Moving like a gigantic metal spider, each of its legs hovers above the ground as it scans below. With a small percentage of its surface area touching the floor, accidental explosions are kept to a minimum.

SPECS
Speed: **12kph**
Weight: **20kg**
Technique: **Explosives**

Central camera
This technology includes a visible-light camera as well as infrared viewing.

Sonar sensors
These sensors send sound waves out, which bounce off objects and return to the robot. This data enables COMET to determine where surrounding objects are, including threats.

Six-legged
Moving independently, the legs use metal detectors and ground-penetrating radar to ensure every step is safe. These radio waves spot any irregularities in the soil, indicating the presence of a buried object. When scanning the floor it uses walking mode for analysis.

SPECS
Speed: **kph**
Weight: **2,120kg**
Technique: **Multiple scanning**

© Getty

How to repel sharks

Can electrical fields help keep these ocean predators at bay?

Sharks have gained the reputation of being cold-blooded killers, weaving their way through the waves on the hunt for their next human meal. It's a stereotype sharks can't shake, and one not actually substantiated by science. In 2019 it was reported that there were 64 unprovoked attacks on humans by sharks worldwide, with a further 41 cases occurring when the shark was provoked, such as removing fishing hooks or when a swimmer attempts to feed or touch them.

Nevertheless, sharks do pose a threat to human marine activities such as diving and fishing, and so tech companies such as Ocean Guardian have come up with a way to use sharks' own biology against them to ward them away. Along with many other animal species, these giant fish have the ability to detect electrical signals emitted through the water – for example from the activity of other fish for the purpose of hunting. The discovery of this built-in electrical receiver created an opportunity to build devices that can disrupt this biological ability and ultimately ward off any nearby sharks, known as shark repellents. Strung from boats or strapped to the body or board of a surfer, these portable devices steer away sharks by emitting electrical signals that disrupt their internal receiver. But how effective are they?

Testing the efficiency of shark repellent technology isn't easy to do, and some members of the scientific community question its effectiveness due to the lack of studies carried out with human subjects, which is an understandable gap in the research. However, some studies that have used these devices in isolation – without the distracting thrashing bodies of ocean swimmers – have shown a surprising ability to keep sharks at bay. One study found that when using one of Ocean Guardian's shark shield gadgets, active devices deterred one-third of sharks when compared to an inactive device at close range. Although the science behind the devices may suggest some success, like most animals sharks can be unpredictable and don't always follow the rules of science. If you're out for a surf with shark repellent strapped to your leg and a big white swims towards you, don't rely solely on electricity to save the day.

© Ocean Guardian

Handheld 'eSPEARS' have been developed to emit electrical fields to deter sharks

© Ocean Guard an

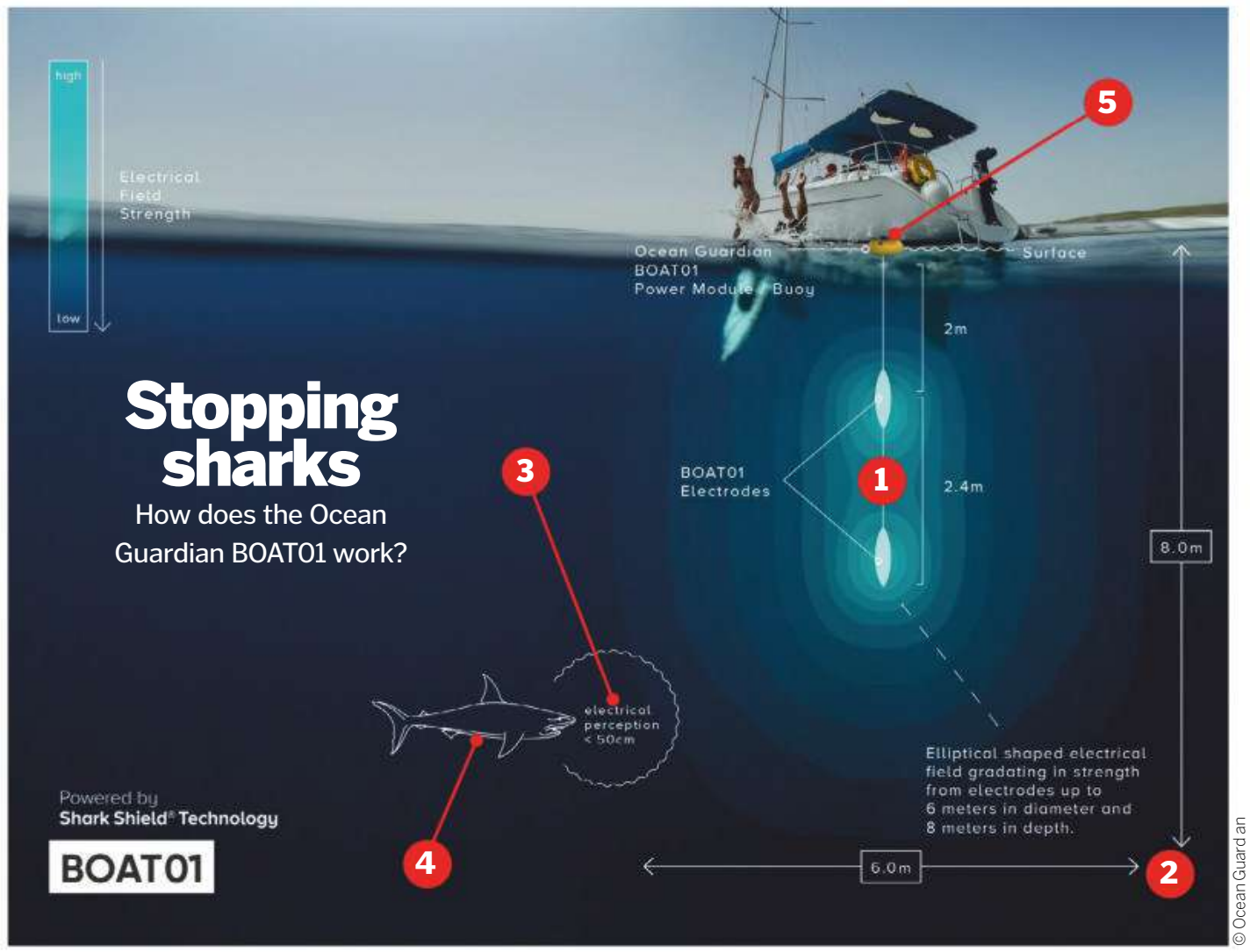
Ocean Guardian Shark Shield technology has been adapted for different activities in the water, like surfing

Smelling electricity

Sharks are well known for their ability to smell the spilt blood of potential prey drifting through the water. However, these stealthy swimmers have also evolved a way to sense the presence of prey by tuning into electrical signals, known as electroreception, beneath the waves. There is a sensory organ – which is known as the ampulla of Lorenzini – that projects into the brains of sharks and acts as a receiver for electrical signals. For example, great white sharks can react to charges of one-millionth of a volt. This comes in very handy when on the hunt for fish because they can react to the electrical fields they produce. For example, the simple act of a fish breathing can discharge a minute voltage when the mucus in a fish's mouth meets the salty seawater.

© Alamy

The electroreceptors can be seen as tiny pores on the snout of a shark



© Ocean Guard an

1 Electrodes
Two electrodes are lowered into the water two metres apart. When submerged the electrodes emit an electrical field around the boat.

2 Range
The BOAT01 emits an electrical field in the water of around eight metres deep and six metres wide.

3 Electrical perception
A shark will perceive the perimeter of the electrical field within less than 50 centimetres.

4 Deterrent
The electrical signal emitted from the electrodes causes muscles spasms, thus deterring sharks swimming closer. Ocean Guardian says this is not harmful to the shark in any way.

5 Power module
A lithium battery bobs on the surface of the water, delivering power to the submerged electrodes for around 12 hours.

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LOCKDOWN nature bounces back

How has the environment fared in the midst of this global pandemic?

Words by **Scott Dutfield**

It's been several months since countries around the world began closing their borders, grounding air travel and quarantining their residents. It's been an unprecedented time filled with uncertainty and anxiety about the future, but could there be a positive environmental effect for a world with people self-isolating?

On average, global emissions of one of the most damaging gases to our environment, carbon dioxide, reach over 36 billion tonnes each year – a figure that has soared from the 2 billion tonnes recorded back in 1900. As a result global temperatures have increased, ice sheets have melted and the world's climate has changed. Human activities such as burning fossil fuels for energy production and increased pollution from travel have been at the forefront of climatic change.

That was, of course, before COVID-19. To prevent this persistent virus from hopping from one host to another, people have been instructed to stay at home. In an attempt to stop the rising number of new cases, the way we once lived has also fallen to the wayside, in turn stifling globally damaging emissions.

One of the biggest contributors to the climate crisis is the industrial and domestic production of greenhouse gases, such as carbon dioxide, which have been increasing at the rate of around one per cent each year. By its very nature carbon dioxide increases what is known as the greenhouse effect, whereby thermal energy is trapped in the atmosphere and heats up the world below.

In April of this year daily global emissions of carbon dioxide fell by 17 per cent when compared to the same time in 2019. These levels were last seen in 2006. Another harmful gas that makes its way into the atmosphere is nitrogen dioxide. This reddish-brown coloured gas has been found to have a more direct effect on human health.

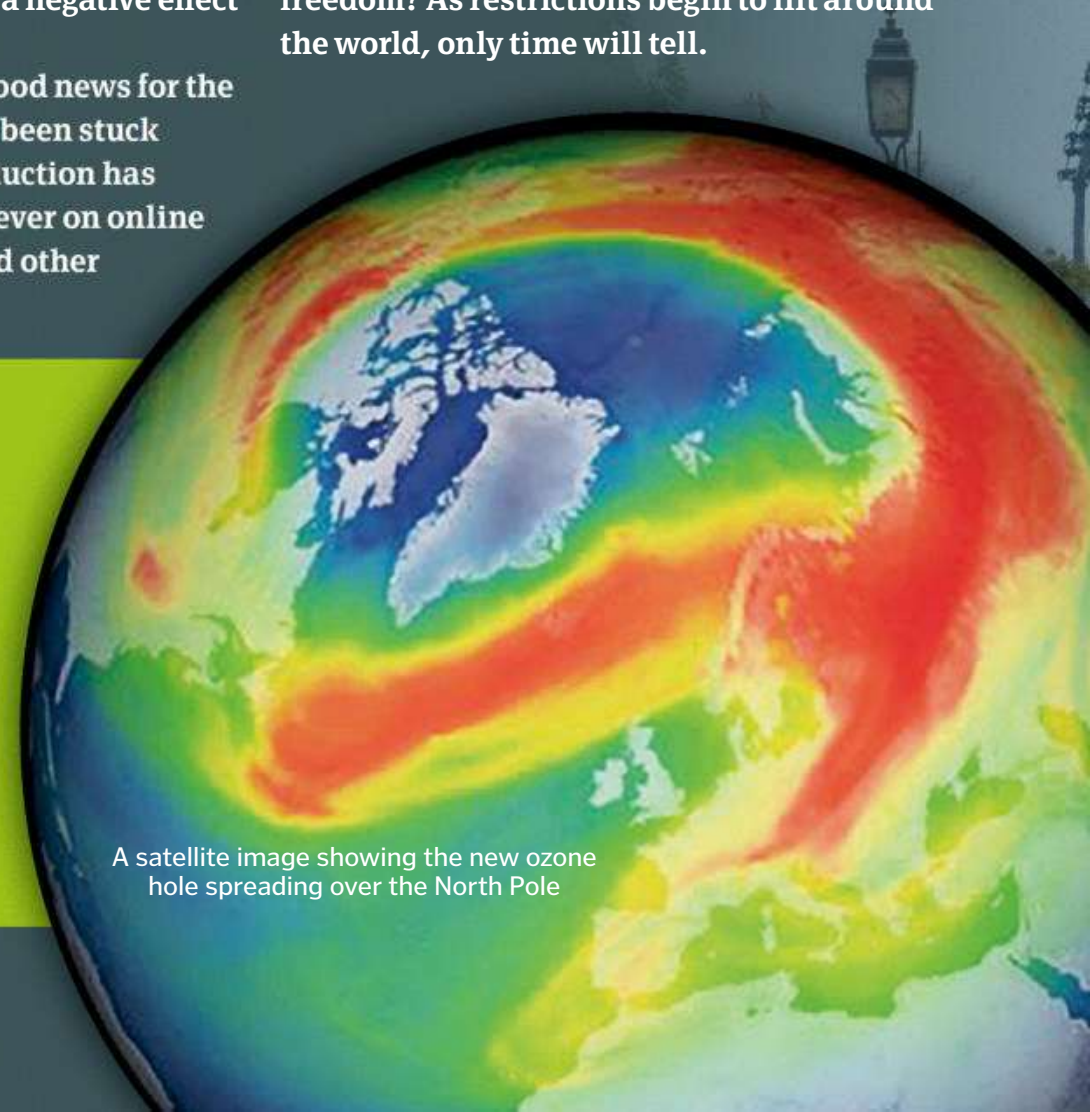
Elevated levels of nitrogen dioxide can cause damage to our respiratory systems, and long-term exposure can lead to chronic lung disease. Around 80 per cent of nitrogen dioxide emissions come from motor vehicle exhausts, and since the number of people on the roads has dropped dramatically during lockdown, satellite imagery has shown that clouds of nitrogen dioxide that were hanging around cities have begun to dissipate.

Our emissions aren't the only thing fading away – environmental noise has also taken a hit. Much more than the blaring music from the world's nightclubs, noise produced from industrial activities can have a negative effect on wild ecosystems.

However, it's not all been good news for the environment. Since we've all been stuck inside, household waste production has soared. Spending more than ever on online shopping for food, clothes and other goods has led to an increase in inorganic and non-biodegradable plastics entering our bins and making their way to landfill. The same can be said for the increased medical waste produced in hospitals.

A recent study found that during the height of the outbreak in Wuhan, China, hospitals produced an average of 240 tonnes of medical waste per day, compared to the typical average of under 50 tonnes. The same study also found that although waste production was on the rise, in countries such as the United States, waste recycling numbers had fallen due to the closure of recycling programs in response to the risk of COVID-19 spreading throughout their centres.

It remains unclear as to what effects global lockdowns may have in terms of climate change. Will reduced emissions continue? Will this unusual period in human history act as an experiment, revealing the possibilities of reduced consumption and restricted travel? Or will this brief breathing space for mother nature once again get choked in greenhouse gases upon our social freedom? As restrictions begin to lift around the world, only time will tell.



A satellite image showing the new ozone hole spreading over the North Pole

Ozone closure

It seems serendipitous that the largest ever ozone hole has finally closed during a period where industries have halted and global emissions may fall to their lowest in a decade. Having spent its time hovering over the Arctic for almost a month, the hole – which was three times the size of Greenland – closed back in late April of this year. This kind of hole is often seen opening annually, although it's rarer at the North Pole compared to the South.

Human-made pollution from industrial chemical pollutants is one reason why these holes open in the atmospheric layer that helps prevent harmful ultraviolet light from reaching Earth's surface. However, there is no known link between lockdown and the hole closing, with scientists saying that the closure is merely a natural correction by a strong polar vortex - it is unrelated to the COVID-19 pandemic.

DID YOU KNOW? *The UK has the second-highest number of deaths attributed to air pollutants in Europe*

India Gate, New Delhi. The smoggy image on the right was taken in November 2019. The clear image on the left was taken just after India went into lockdown, on 30 March 2020

© European Space Agency

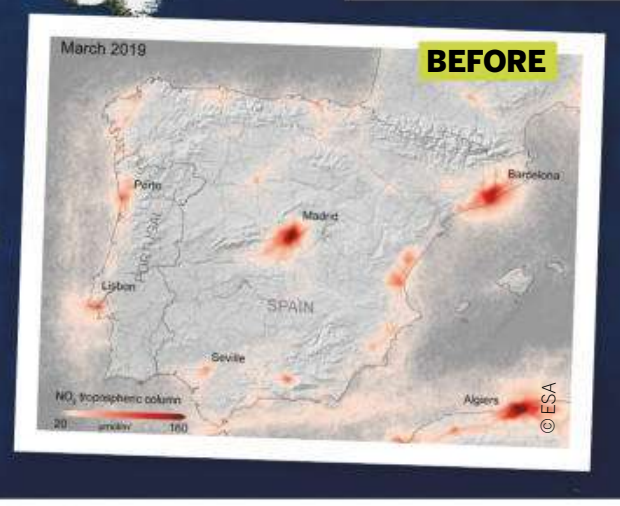
© Getty

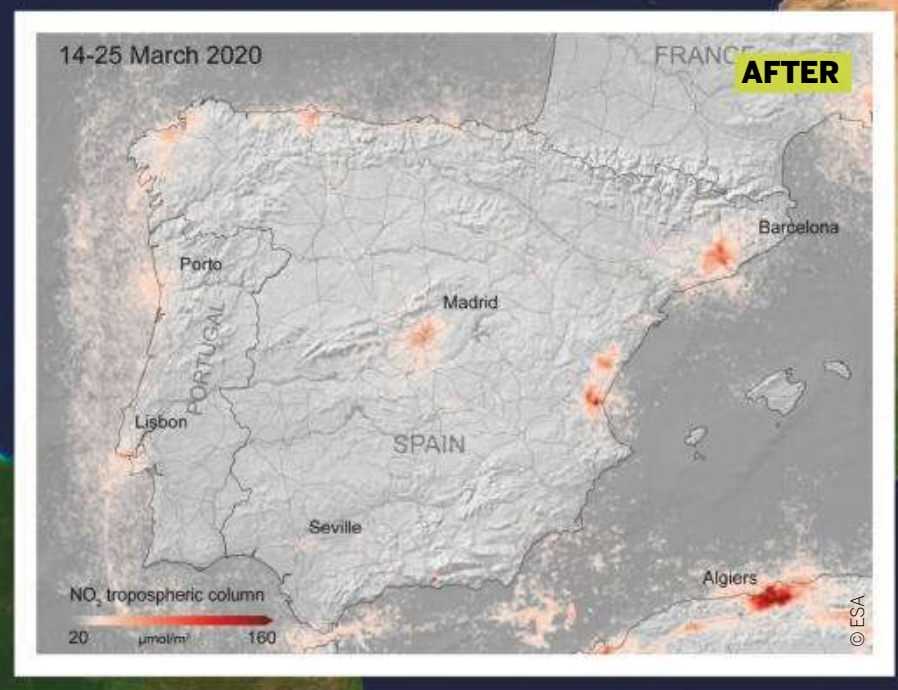
EMISSIONS *under lockdown*

How have the emissions of some of the countries affected most by COVID-19 changed since lockdown?

Spain

There has been a high decline in nitrogen dioxide emissions across some of Spain's major cities, such as Barcelona and Seville, with the country's capital Madrid showing a reduction of 56 per cent week-on-week since the government imposed a non-essential travel ban on 14 March.

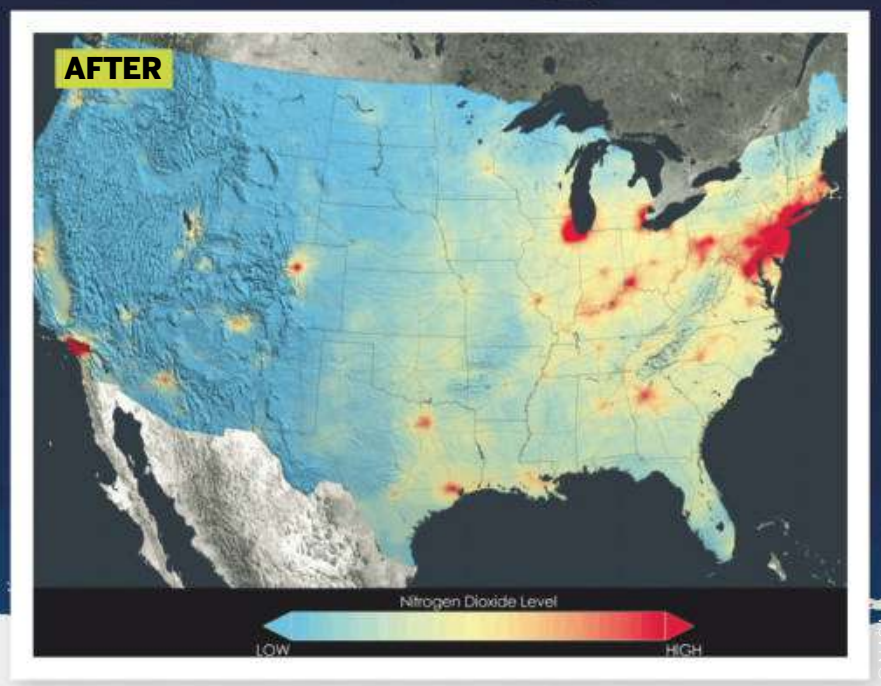




United States

Average emissions of nitrogen dioxide are typically high throughout the United States. However, since lockdown restrictions were applied in March the country underwent a reduction in emissions of 30 per cent.

© NASA

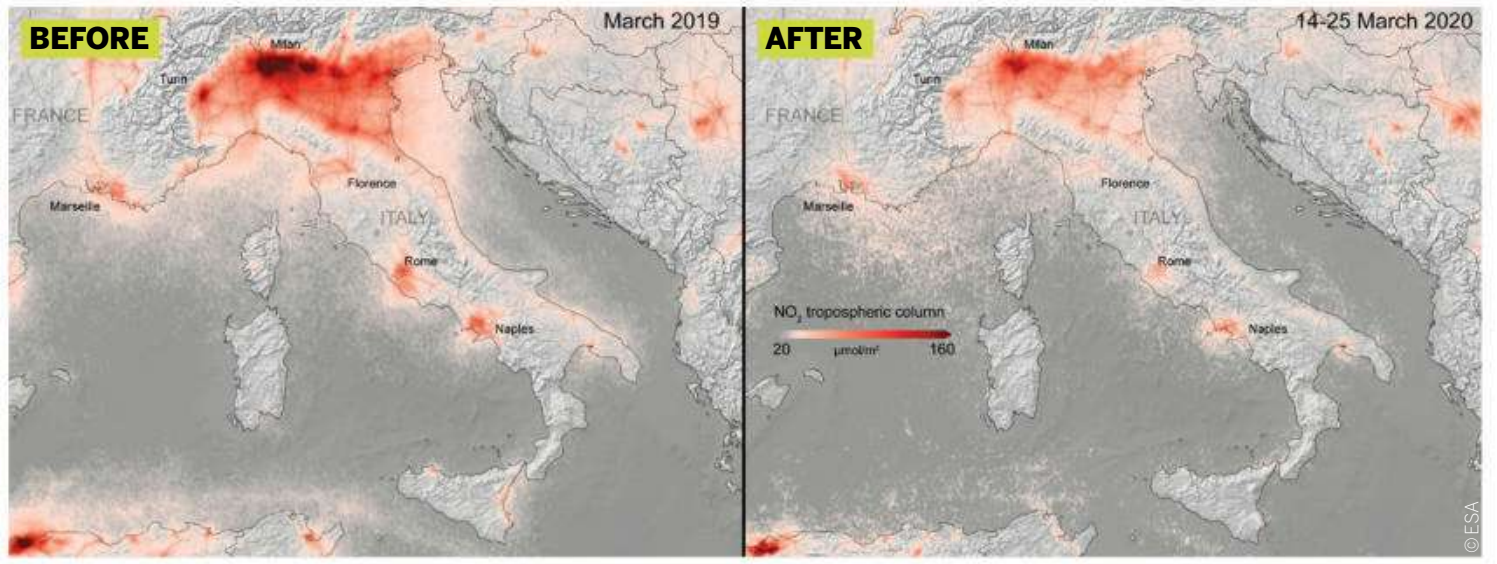


© NASA

Oxford Circus, London, on 3 April 2020

© Getty

DID YOU KNOW? *In Europe in March, average temperatures were two degrees Celsius higher than the 1981 to 2010 average*

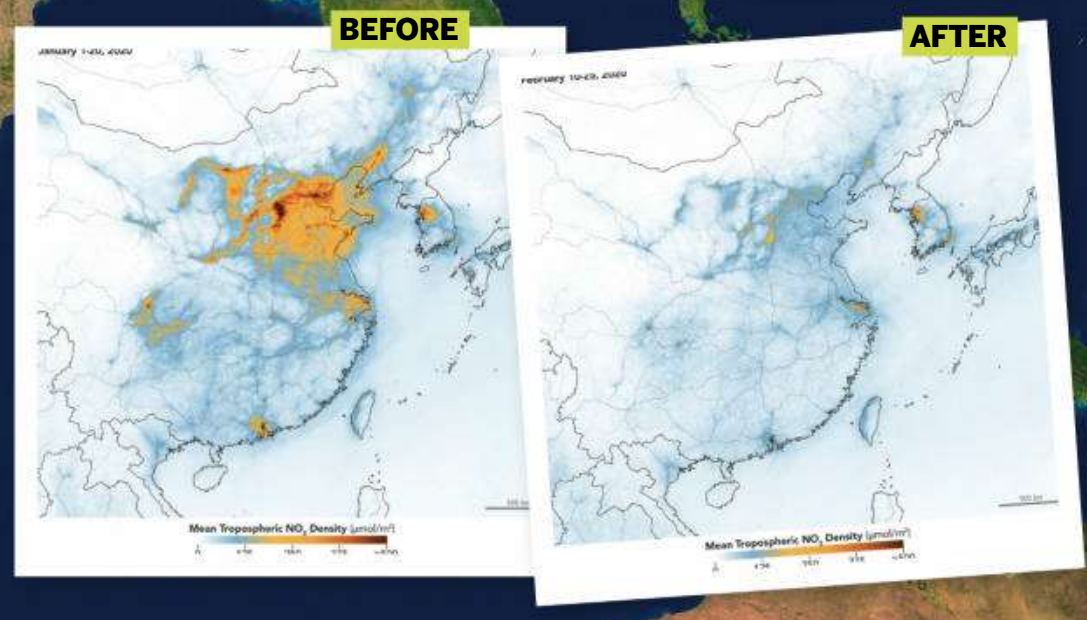


Italy

Like France and Spain, Italy has joined the club of countries reducing nitrogen dioxide emissions around its largest cities. Satellite imagery has shown that the capital of Rome has seen a 49 per cent drop in emissions during lockdown.

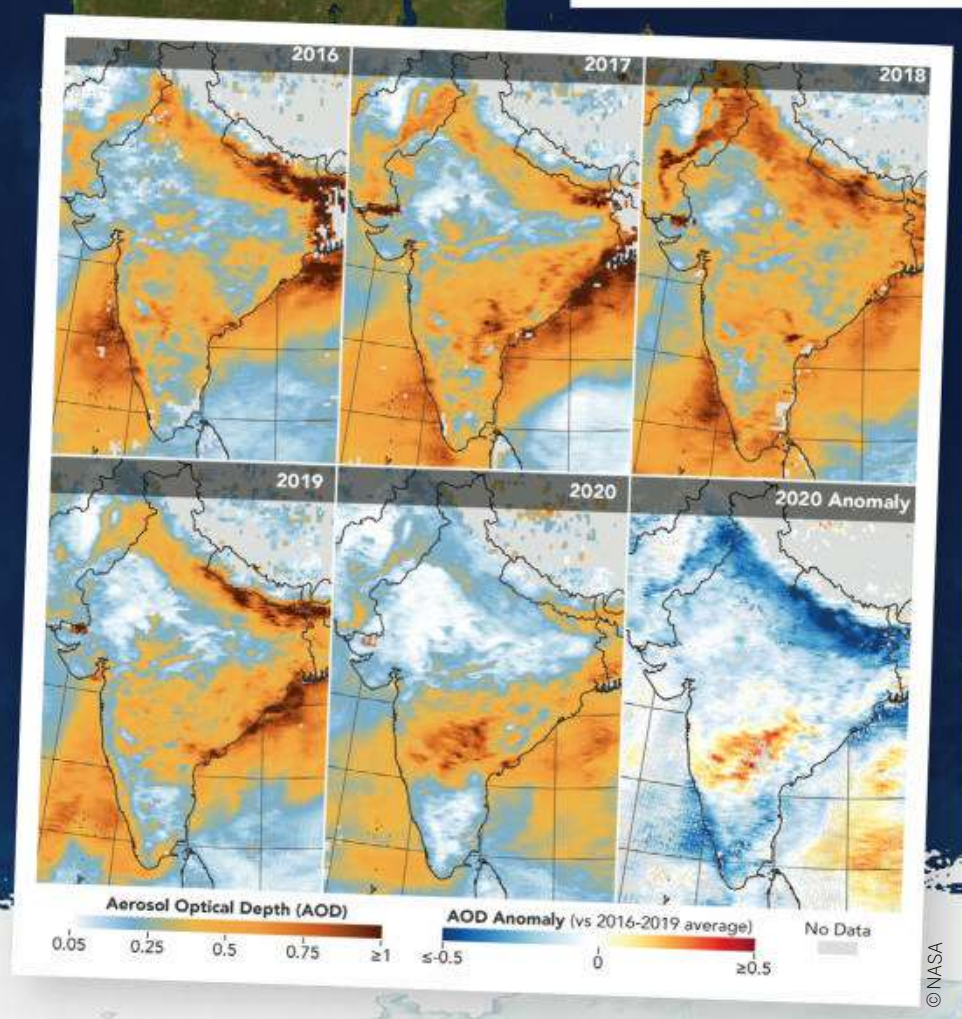
China

As the first country to put lockdown restrictions into place, the nation has seen some dramatic drops in it's nitrogen dioxide levels. It's estimated that 40 percent of the nation's NO2 emissions have dropped during lockdown due to it's reduction of burning fossil fuels.



India

With a population of 1.3 billion people, India is one of the world's largest air polluters. Since restrictions were imposed northern India's aerosol or tiny particle pollutants have decreased to a 20-year low for the time of year.



The extinction of ecotourism

In a world where people have been quarantined away from wildlife, you may assume that this can only be of benefit to nature, and in some cases it is. However, much like the retail and service industries, ecotourism has been hit hard by the lack of people who can come and support the great work of conservationists around the world. Helping to protect endangered species through paid excursions and donations, ecotourism has played a vital role in conservation for decades. However, the future of this conservation strategy is under threat due to travel restrictions. Wildlife organisation Fauna & Flora International has suggested that 50 million tourism jobs are forecast to be lost in 2020, leaving the industry as a whole as desperate for support as the species and environments it seeks to protect.

© Getty

Tanjung Puting National Park, Borneo, is home to orangutans that often greet visitors

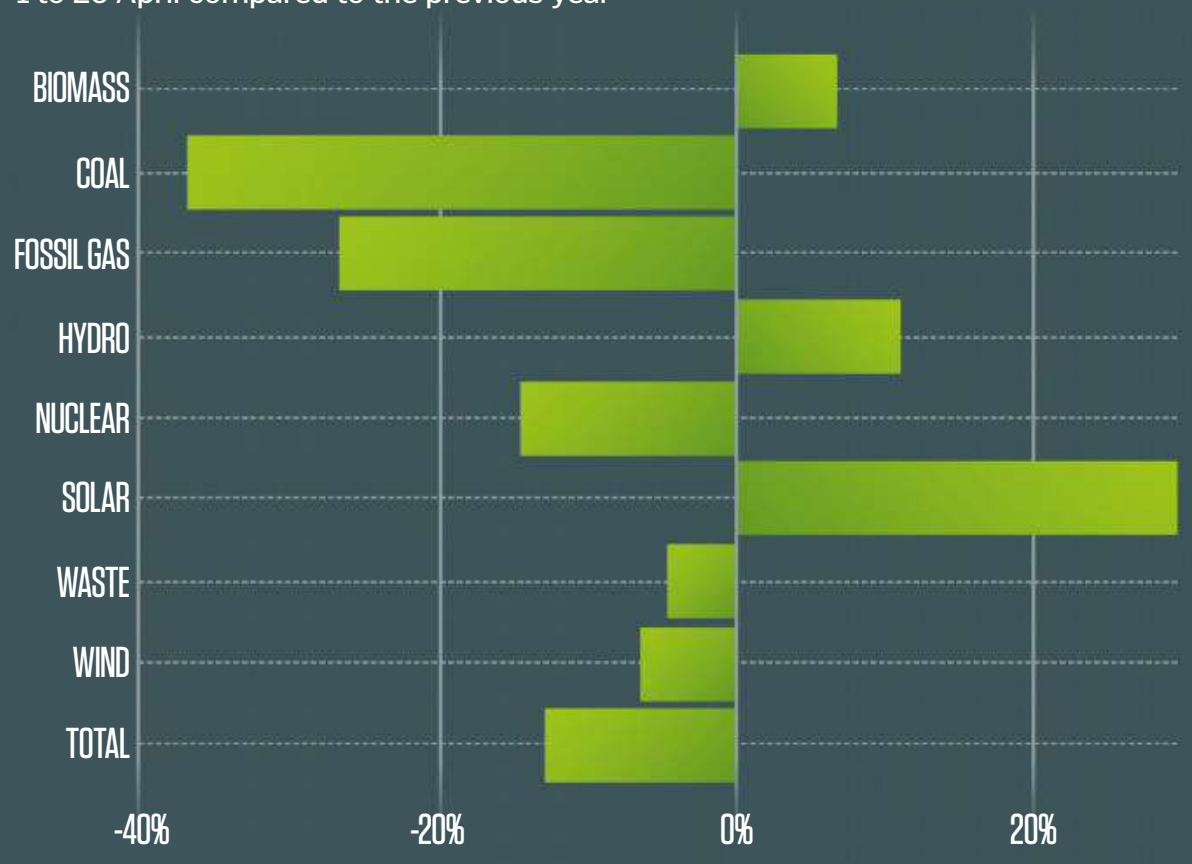
© Getty

LOCKDOWN *by numbers*

How the environment has changed since global lockdown

GLOBAL POWER GENERATION

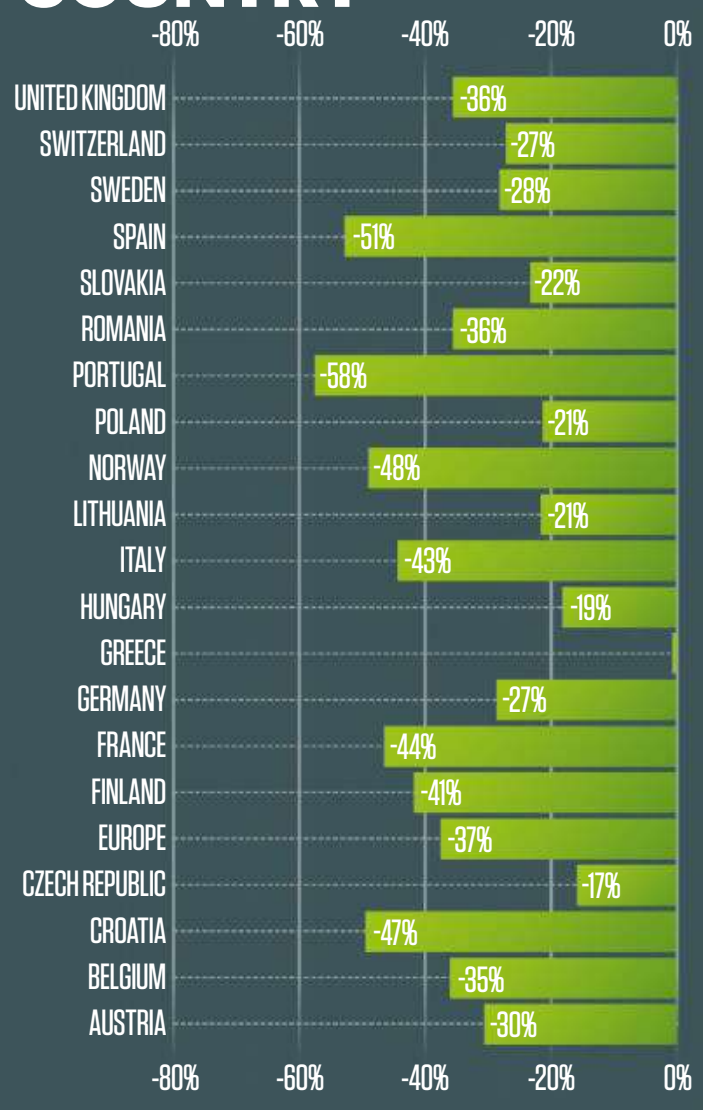
1 to 26 April compared to the previous year



WORLD'S LARGEST QUARANTINES

India **1,380,000,000**
China **760,000,000**
United States **297,000,000**
Bangladesh **165,000,000**
Russia **142,000,000**
Philippines **100,000,000**
United Kingdom **68,000,000**
France **65,000,000**
Italy **60,000,000**
South Africa **59,000,000**

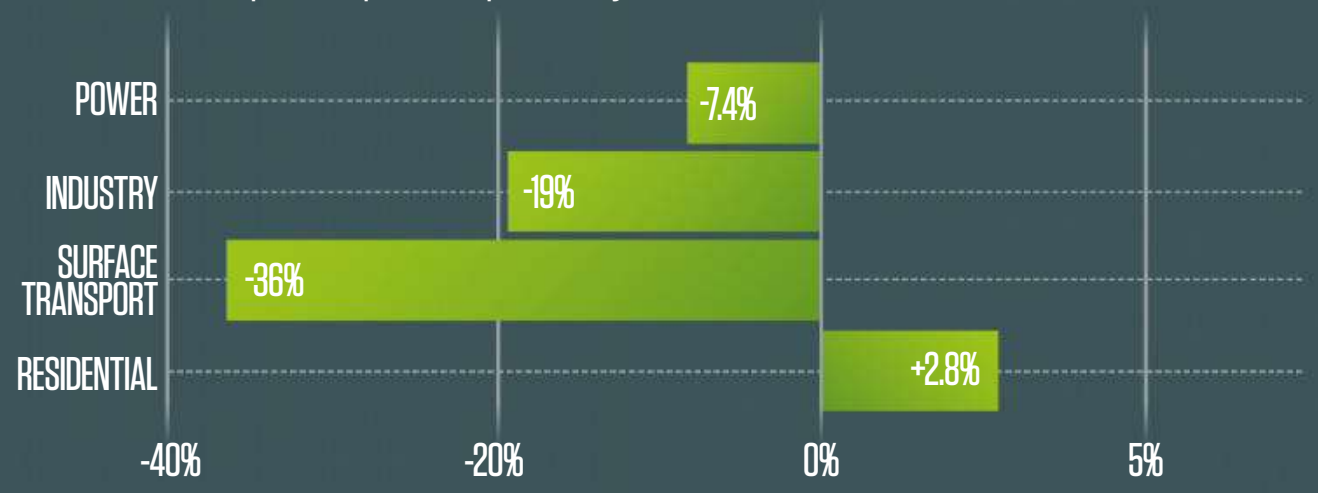
NITROGEN DIOXIDE REDUCTION BY COUNTRY



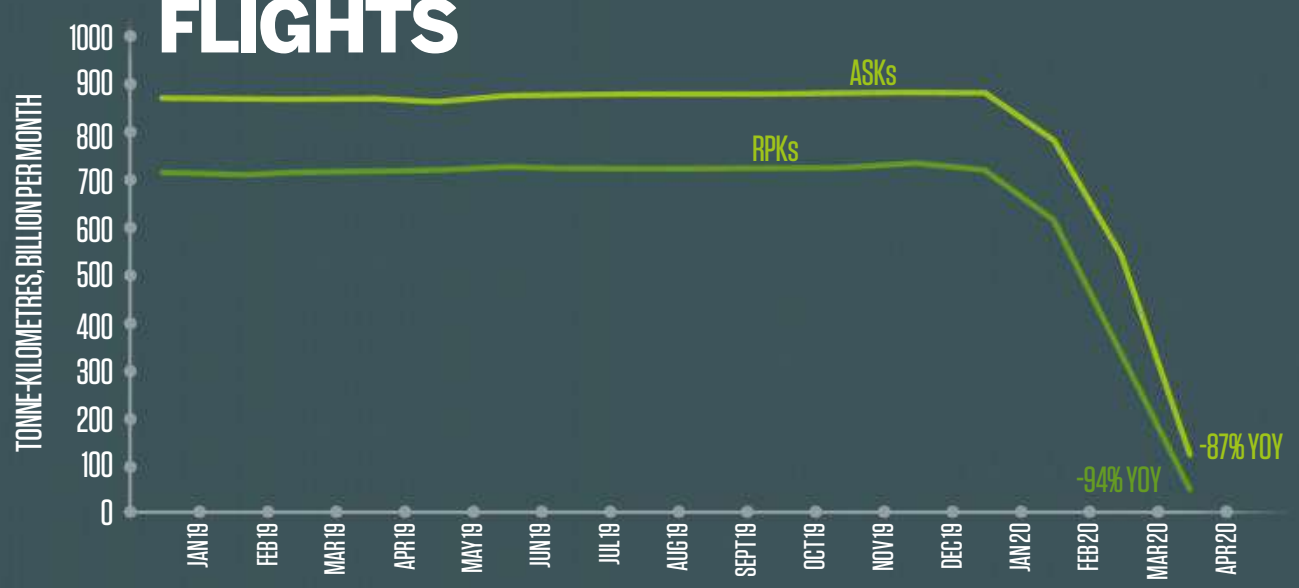
Data courtesy of IATA, CREA

CHANGE IN GLOBAL CO_2 EMISSIONS

Taken from 7 April compared to previous year



FLIGHTS



© ESA

The Venetian canals have become crystal clear without the constant boat traffic

Banning bat meat

It's been widely reported that the coronavirus outbreak originated from the consumption of bat meat in the pandemic epicentre of Wuhan, China, from what is known as a zoonotic pathogen, a virus that jumps from an animal to infect a human. Although the origins of the virus are still relatively unknown, calls for China and the rest of the world to curb the sale of exotic animals as food have grown louder in recent months for fear that another pandemic is just a bite away.

With more than just bats on the menu, Chinese 'wildlife markets' stock wild animals as bushmeat, a practice that was legal until a ban was enforced on 26 January this year. However, the ban does not prevent 'wildlife farmers' from breeding exotic animals for meat. It's believed that two provinces in China are offering a buy-back scheme for farmers to transition to alternative livelihoods. Farmers are reportedly being offered 120 yuan (around £13) per kilogram of cobra, 630 yuan (about £70) per porcupine and 600 yuan (about £67) per civet cat. This is, however, not an issue resting solely on the shoulders of China, but one that reaches around the world.

© Getty

The Tomohon Extreme Market on Sulawesi island, Indonesia, offering exotic meats such as snake, bat and rat, taken in February 2020

Q&A

A POST-LOCKDOWN PLANET

© University of Leeds

What might the world be like once global restrictions are lifted? We speak with the director of the Priestley International Centre for Climate and professor of physical climate change at the University of Leeds, Piers Forster, for his thoughts on the environmental implications of lockdown

How has lockdown in various countries impacted global emissions?

One of the biggest changes has been in India, but it is countries with the biggest restrictions where we've definitely seen the biggest changes. Most of the emissions changes come from changing transport. It's with the nitrogen dioxide pollutants we have really seen the biggest decline, and that has really come from the reduction in the number of cars on the roads. There has also been a reduction in demand for electricity, particularly by industry, and the interesting thing about that demand is there's probably been a bigger decline in emissions than we have seen in the decline of demand. That doesn't mean that in countries, again like India, they're choosing to turn off their coal firepower, but they are keeping their renewable power working. We've seen this big change in demand going from coal and fossil fuels to more renewables.

"It's with the nitrogen dioxide we have seen the biggest decline"

Could data being collected act as evidence of how the world can function better?

I think it's a really good experiment to see how much we can change our behaviour and how some of the business alternatives can really change. They've been trying to introduce online consultation, for example, within the NHS for the last five years, and they did it over a five-day time period – they almost went 100 per cent online. I think that would indicate that businesses can change and individuals can change their behaviour, and they can do it over a relatively short space of time. We can also discover which of these possible changes are sustainable and which ones are not. In other words, we can discover which other jobs you can do this with and which jobs you cannot. It's also an experiment on how much we can clean up the air and what changes to our environment are within our powers.

Could there be any unforeseen strains on the environment as a result of lockdowns?

In terms of the environmental side, it isn't obvious, but I am pretty sure that some will come out eventually. But I do think generally it has been almost 100 per cent beneficial for the environment. The caveat that comes with that is the effect of this coronavirus crisis on the economy, because quite a lot of charities and government policy investments will depend on a robust economy. If we are going to get to a net-zero target [in emissions] and we are going to clean up our beaches and move to electric cars in society, these things require a really good economy.

I would say that I can't think of an immediate detrimental effect of COVID-19 [on the environment], but I think there could be quite a detrimental effect from COVID-19 if we don't recover from it in the correct direction. We have to think carefully about what our economic priorities are when we come out of COVID-19.

Why this lake is pink

Meet the salt-loving cells responsible for painting Lake Hillier its lurid colour

Words by **Ailsa Harvey**

On an island off the coast of Western Australia, you might expect the abundant sunshine to highlight a feast of colour for your eyes. However, the turquoise of the shallow waves and sun-kissed greens in the trees of Middle Island are interrupted by a contrasting body of intense pink. Though an irregular shade to grace any of Earth's natural landscapes, this is no trick of the eye. This is Lake Hillier, an entirely pink lake.

After its discovery in 1802 by a Royal Navy explorer, it was soon realised that this lake was as rich in salt as it was colour. The lake has a salt concentration around ten-times higher than the ocean that surrounds the island. This made it a prime target for salt miners, who extracted the mineral from it for years. Today, however, the natural wonder is protected, and the lake serves mainly as a tourist attraction. Onlookers gaze in awe at the delightfully pink tones, bordered by its dry-salt shore, with many asking how it is possible for a lake to be so pink.

As much as the lake resembles a human-made pool of strawberry milkshake, the answer to this question comes only from nature. Lake Hillier is thought to gain its colour mainly from a microorganism called *Dunaliella salina*. This algae has adapted to thrive in the lake's extremely salty conditions using a pink pigment to survive the high salt concentrations that are toxic to other organisms.

Being on an island and surrounded by dense forest makes the lake difficult to reach

Pink producers

There are no fish or other wildlife to be seen in the peculiar pink waters, but what it lacks in fish it makes up for in microorganisms. Being one of the few species able to thrive in this lake, the huge population of *Dunaliella salina* algae is reflected in the colour. They produce carotenoid pigments called beta-Carotene, and it is this that scientists believe produces the vibrant pink.

Other microorganisms found in the lake which contribute to the pink hue are the halophilic archaea *Halobacterium salinarum* residing within the salt crusts. The term halophilic means 'salt-loving', which all organisms in Lake Hillier have to be to stand a chance of living in those conditions. With tough cell walls, these are capable of living in some of the world's most extreme environments – and they also happen to be pink.

Dunaliella salina is a green algae that turns pink through pigment production

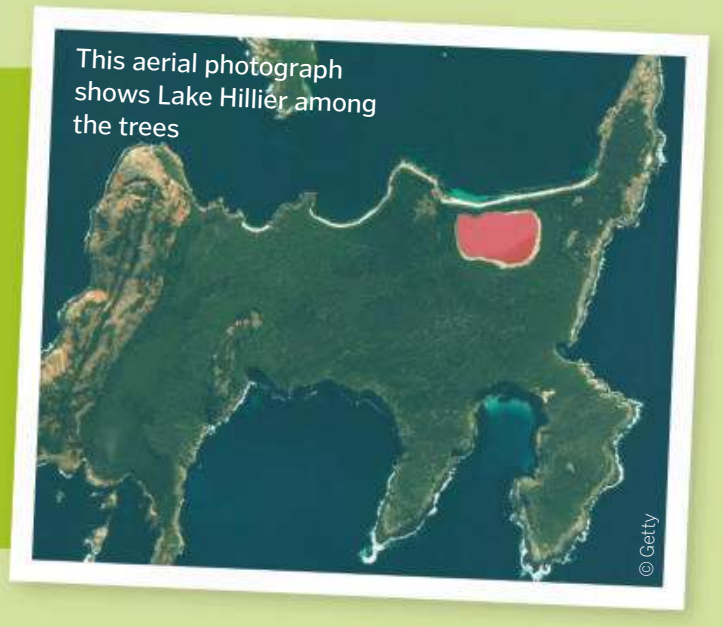
© Science Photo Library

© Getty

Why so salty?

Salt lakes form when water that enters the area can't leave again. While the salt and other nutrients it is carrying have come to a dead end, the water can evaporate into the air. As this process continues, the water level remains fairly constant, but the salt begins to accumulate.

They typically form inland, as when they are connected to the sea their concentrations can become diluted. When salt concentrations get so high that all other life dies out, salt-loving algae and bacteria have less competition and multiply in number. Pink lakes can fluctuate in colour as water levels change, but the pigment-bearing microorganisms in Lake Hillier are prevalent enough to keep the lake pink all year round.


This aerial photograph shows Lake Hillier among the trees

© Getty

5 FACTS ABOUT PINK LAKES AROUND THE WORLD

1 Lake Retba, Senegal

© Getty

As one of the saltiest lakes in the world, rivalling the likes of the Dead Sea, swimming in this lake makes you incredibly buoyant.

2 Lake Natron, Tanzania

© Alamy

In East Africa, this lake creates a salty substance called natron. Natron consists of sodium carbonate decahydrate, sodium bicarbonate, sodium sulphate and sodium chloride.

3 Sivash Salt Lagoons, Ukraine

© Alamy

The high salt levels make this lake incredibly popular for salt mining, but the smell is not as lovely as the sight. It has been nicknamed 'Rotten Sea'.

4 Lake Tuz Gölü, Turkey

© Alamy

Found in Central Anatolia, this pink lake is one of the largest salt lakes on the planet, with a surface area of 1,600 square kilometres.

5 Pink Lake, Australia

© Alamy

Another pink lake in West Australia, this lake can be found in Esperance. Despite its name, many tourists are disappointed to find Pink Lake is no longer pink. It is believed to have lost its colour from salt mining and may soon be given a name change.

Survival in salt

How does *Dunaliella salina* survive in extreme salinity?

Beta-Carotene

Dunaliella salina produces carotenoids. These are fat-soluble pigments that create the pink hue and help the algae absorb light.

Thin membrane

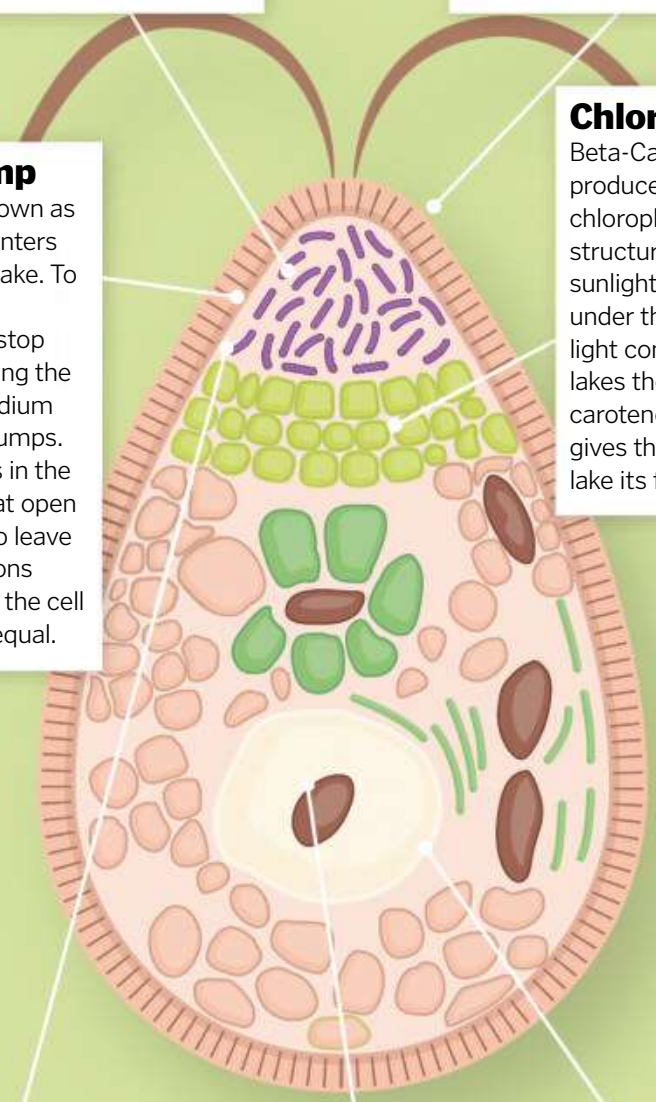
The microalga doesn't have a rigid cell wall. This allows them to quickly fluctuate the water volume inside the cell by osmosis.

Sodium pump

Salt, otherwise known as sodium chloride, enters the alga from the lake. To control its internal conditions and to stop high salt levels killing the cell, it removes sodium through sodium pumps. These are proteins in the cell membrane that open to allow the ions to leave when concentrations inside and outside the cell need to be made equal.

Chloroplasts

Beta-Carotene is produced in the chloroplasts. These structures absorb sunlight for growth, but under the intense UV light common in salt lakes they create carotene. This pigment gives the algae and the lake its famous colour.



pH gradient

Dunaliella salina has pumps that work to match acidity levels in the lake and the cell instead of just salt concentrations. This allows the alga to push sodium out of the cell against the concentration gradient. Sodium ions are able to leave the cell even when outside conditions are saltier. This method prevents deadly salt levels accumulating inside.

DNA protection

The carotene made in the cell helps to protect DNA from UV light. It does this by absorbing the light, preventing direct damage to the cell.

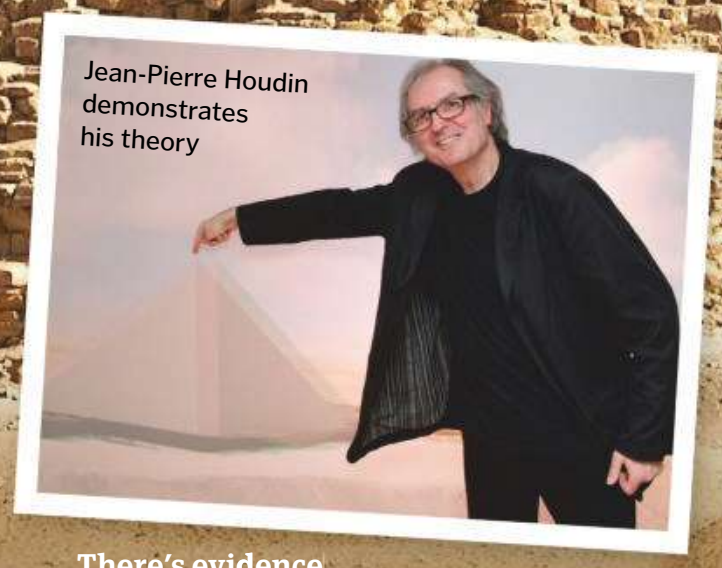
Glycerol production

If the cell begins to lose liquid due to an increase in salt outside the cell, *Dunaliella salina* makes glycerol. Matching the outside concentration, this molecule acts in a similar way to the salt in the lake and draws water back into the alga. Using glycerol means the cells can reduce internal salt concentrations stably.

© Illustration by Ed Crooks

Mystery of the Great Pyramid

The theories of French architect Jean-Pierre Houdin may hold the key to an ancient mystery



Jean-Pierre Houdin demonstrates his theory

Although Egyptologists have been studying the Great Pyramid of Khufu for centuries, they haven't yet reached a consensus on how exactly it was built. How were the massive two-tonne blocks placed almost 150 metres above the desert floor? A French architect named Jean-Pierre Houdin has formed a theory to explain the mystery. Houdin has devoted his time to studying the Great Pyramid and creating graphical models using 3D software.

Houdin believes that an external ramp was built to haul the rocks – pulled by means of ropes – for the first 60 metres or so of the pyramid. Then an internal ramp was built to continue hauling rocks up. It is a narrow structure spiralling inside the pyramid, much like the ramps in a parking garage. To allow for men to haul the stones, the ramp is at a seven per cent slope. Somehow it has remained hidden inside the pyramid since its completion 4,500 years ago.

However, how would men hauling the blocks up the ramp be able to make the turn at each corner of the ramp? They would need a place to stand and pull ahead of the blocks. Houdin believes that each corner was temporarily left open. Wooden cranes were stationed in each of these open spaces to lift and turn the blocks onto the next part of the internal ramp. Later these notches were filled in.

There's evidence that an internal ramp exists. In 1986 a team of French scientists used microgravimetrics to survey the pyramid. They were looking for hidden chambers by checking for areas of low density, which would indicate open spaces. The team did find one new chamber that was filled with sand. However, one diagram puzzled them – there appeared to be a low-density spiral inside the pyramid. In 2000 a member of the team met with Houdin and showed him this scan, which lends weight to his internal ramp theory.

During a 2007 visit to the Great Pyramid, Egyptologist Bob Brier pointed out two more

Building a pyramid from the inside out

The Great Pyramid has both ascending and descending chambers

The King's Chamber
This is the main chamber of the pyramid. Unlike later pyramid chambers, its walls are blank. A granite sarcophagus sits inside, but no lid has ever been found.

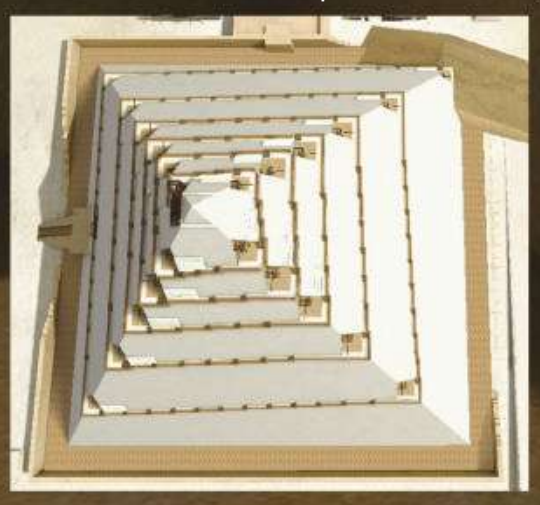
The Queen's Chamber
The name of this chamber is a misnomer. Many Egyptologists believe that it was originally built for Khufu. However, as he was still living when the chamber was finished, it was abandoned.

Unfinished subterranean chamber
This chamber lies below ground level. It may have been built in case Khufu died early, but he may have also simply changed his mind about where he wanted to be buried.

Relieving chambers
Houdin believes that these chambers were built to relieve weight on the King's Chamber. Others think that they were for ventilation or to allow Khufu's soul to rise to heaven.

The Grand Gallery
This long, narrow room slants upwards. It has a corbelled ceiling and benches along its sides, with slots cut into each bench. Egyptologists aren't quite sure about its use.

The entrance
The entrance wasn't created until 820 CE by Caliph Al-Ma'mum, who tunnelled into the pyramid so it could be searched for treasure. The original entrance was sealed after the pyramid's completion.



According to Houdin, openings were left at the corners so workers could use the internal ramp

features that could be evidence of the ramp. When the Sun hits the pyramid at a certain angle, you can see broad white lines at a seven per cent incline running around it.

Brier climbed the pyramid to examine what appeared to be a notch, and although it had irregular measurements, there was a small chamber that he had never heard about before. It could be the remains of the open notch leading to a ramp. In addition, Brier has pointed out that the Sun Temple, built 100 years after the Great Pyramid and now partially in ruins, contains an internal ramp. This shows that the Egyptians were building these types of ramps.

Working with the former director of the German Archaeological Institute, Houdin has petitioned the Egyptian Supreme Council of Antiquities to survey the pyramid in a non-destructive way. If he gets the go-ahead to do so, he may be able to prove his theory after all.

This side view shows the internal ramp snaking up through the pyramid's interior

The old theories debunked

Houdin's theory is very different from the traditional theories

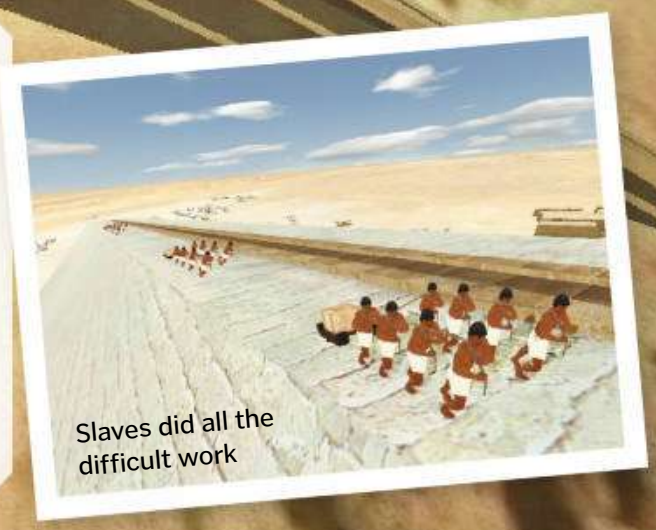
Plateau
The pyramid is built on a plateau. Its north side has a very steep drop-off, making it unsuitable for the placement of an external ramp.

External ramp
Many Egyptologists believe that an external ramp was used to build the pyramid. This would have been massive and required nearly as many stones as the pyramid itself to build.

Cemeteries
The pyramid has cemeteries to its east and west, which were built at the same time. This means that an external ramp could not have been placed there.

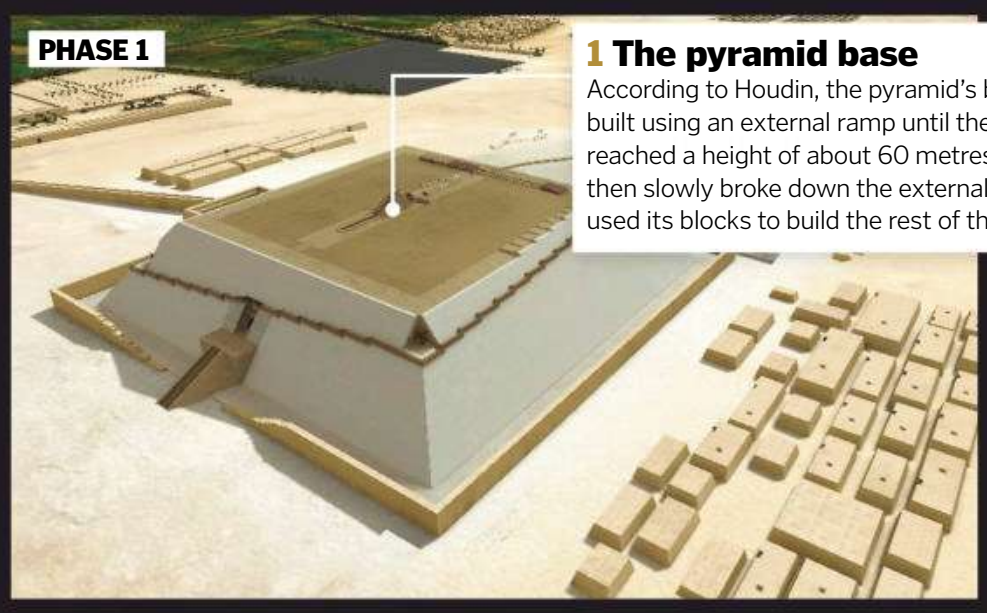
One common theory states that an external ramp was used to haul the blocks all the way to the top. The problem is that there isn't anywhere around the pyramid to place a ramp of this size. The pyramid is built on a plateau, with a steep drop to the north. Cemeteries were built at the same time as the pyramid to its east and west. In order to maintain the correct seven per cent slope all the way to the top, a ramp built to the south would've been about 1.6 kilometres long. This huge undertaking of labour and use of materials seems impractical.

Another theory maintains that there was a spiral ramp coiling around the outside of the pyramid. But this type of ramp wouldn't have allowed the pyramid's architect, Hemiunu, to maintain the sight lines necessary to ensure that the pyramid's faces met correctly at its top.


Slaves did all the difficult work

BUILDING A PYRAMID STEP-BY-STEP

Houdin's theory posits that the pyramid was built with two ramps



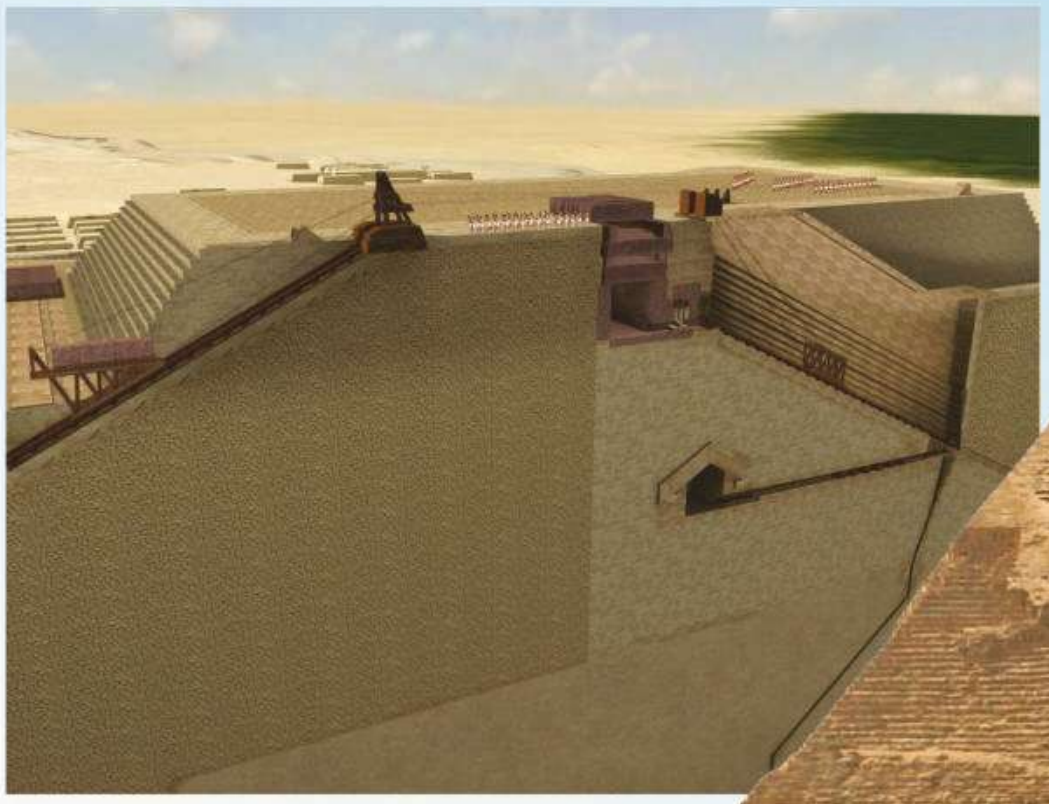
1 The pyramid base
According to Houdin, the pyramid's base was built using an external ramp until the base reached a height of about 60 metres. Workers then slowly broke down the external ramp and used its blocks to build the rest of the pyramid.

2 Starting the internal ramp
As workers continued building the rest of the pyramid, they also built and used an internal ramp to haul the heavy blocks. This allowed them to build the pyramid from the inside out.

A search for truth

Dr David Jeffreys, an Egyptologist at University College London, has suggested that Houdin's theory is "far-fetched and horribly complicated". Houdin has countered this by saying that his theory is actually no more complicated than the idea of building a 1.6-kilometre-long external ramp leading up to the top of the pyramid.

Dr Zahi Hawass, Egypt's former Minister of State for Antiquities Affairs, seemed to initially consider Houdin's theory as a possibility. However, in a 2009 interview Hawass stated that Houdin's theory is "completely wrong" and "the theory of other theorists". Houdin invited Hawass to lead the survey of the pyramid.



However they did it, the feat of constructing the pyramids is incredible

Head-to-head PYRAMIDS

1. Great Pyramid of Cholula

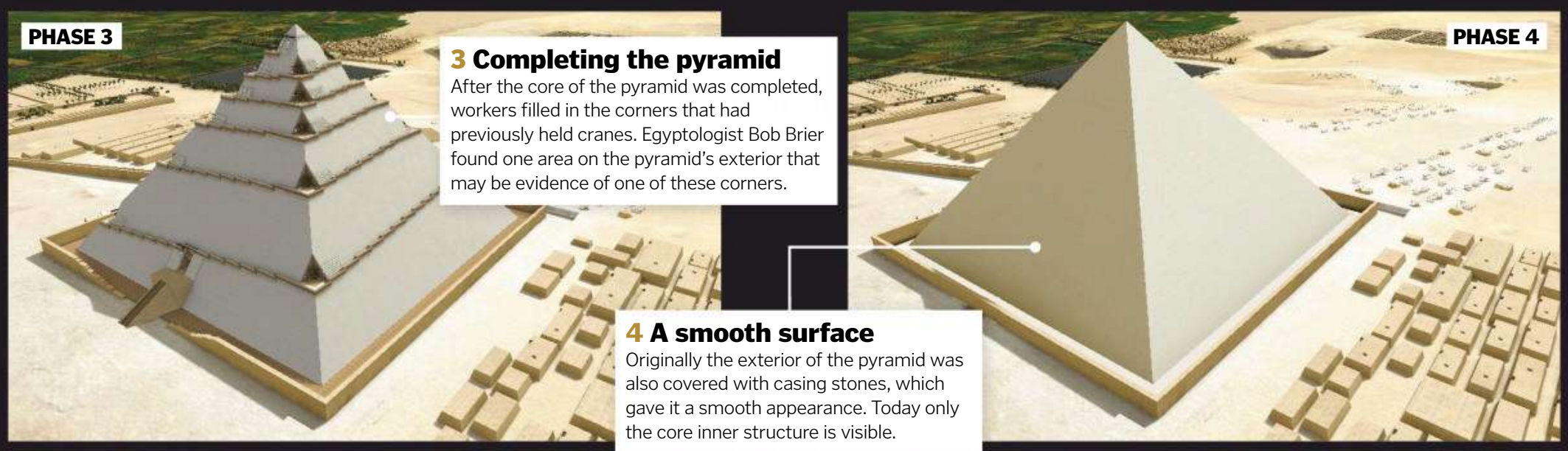
Location: Cholula, Puebla, Mexico
Height: 54 metres
Estimated age: 1,000 years
Fact: This pyramid was built in four stages and has a volume of about 4.45 million cubic metres.

2. Pyramid of Djoser

Location: Northwest of Memphis, Egypt
Height: 62 metres
Estimated age: 4,600 years
Fact: Built for the pharaoh Djoser, this pyramid comprises six steps built in stages.

3. Ryugyong Hotel

Location: Pyongyang, North Korea
Height: 330 metres
Age: 28 years
Fact: Although not ancient, this 105-storey skyscraper is the tallest pyramid in the world. The interior isn't finished with no scheduled completion date.

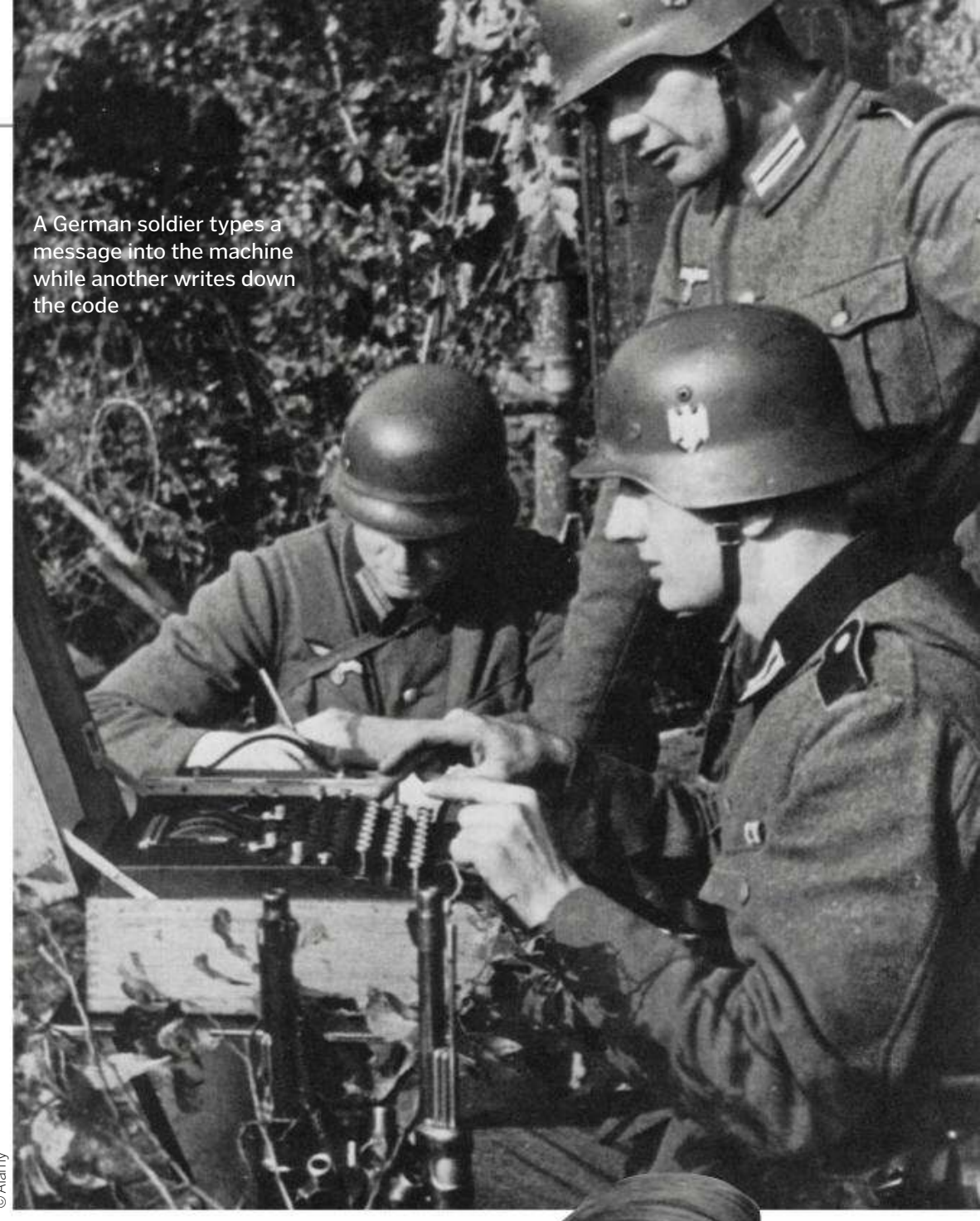


3 Completing the pyramid
After the core of the pyramid was completed, workers filled in the corners that had previously held cranes. Egyptologist Bob Brier found one area on the pyramid's exterior that may be evidence of one of these corners.

4 A smooth surface
Originally the exterior of the pyramid was also covered with casing stones, which gave it a smooth appearance. Today only the core inner structure is visible.

The military version of the Enigma had a plugboard to increase security

© Getty



A German soldier types a message into the machine while another writes down the code

© Alamy

How Enigma made secret messages

How did this machine encrypt confidential wartime communications?

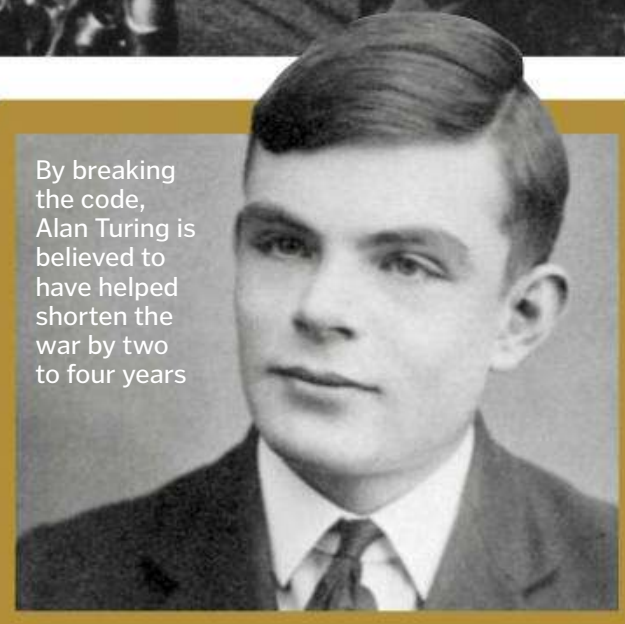
Words by **Ailsa Harvey**

Communicating plans during World War II was no easy feat. How do you share a message between all your troops and allies at a time when your every move is being analysed by the enemy? How do you ensure that the messages will make it into the right hands? The answer for German forces came in the form of the Enigma machine, and while it was an enigma to the opposition, the system would eventually be cracked.

The electromechanical machine worked to replace every letter in the message with an encrypted, seemingly nonsensical substitute. As electrical signals passed through the device, a series of rotors and wires would divert the path to new letters. What earned the Enigma machine its name was the lack of a consistent pattern derived from results. Every day the German military would change the set-up and components of the machine so that they couldn't easily be deciphered. All this required was the sender and receiver to arrange their machines in the same positions.

When Britain's brainiest mathematicians finally worked out how to crack the code in 1941, the intricate system was revealed, along with numerous secret messages and the opposition's war plans. The curious machine that gave Germany an advantage in the early stages of war could now play into the hands of Britain and the Allied forces.

"The electromechanical machine worked to replace every letter in the message"



By breaking the code, Alan Turing is believed to have helped shorten the war by two to four years

Who cracked the code?

At the height of the war, Britain's top geniuses were needed if they were going to understand a system that changed its settings by the day. Fortunately the British Government's Code and Cypher School had just that. Alan Turing was an English mathematician who was already working on the Government's code team before the war broke out.

His logic skills and experience led to him creating the 'Bombe' machine, a device that could be used to detect the settings of the Enigma machine used. The Bombe was able to process multiple variations at one time and display successful results that read in German. This meant that the daily rotor changes were no longer an obstacle and code cracking could be done much quicker.

Inside the machine

What components create the code?

Inner lid
This lid can open to change internal settings, but is folded down for use.

Reversing wheel
When the electrical current has moved through the three rotors, it reaches the reversing wheel. This sends the current back through the system using a different route to the one it took to arrive.

Lampboard
Situated above the keyboard, these letters match up with those on the keys, each having a bulb beneath it. When a letter is typed, the coded letter lights up. This is noted and written down to form a seemingly meaningless sentence.

Keyboard
With a similar design to a common typewriter, letters on the keyboard are pressed to type the message the sender wishes the receiver to read when it is unscrambled.

Ring slots
Next to the windows, these slots can be turned to change the starting letter on each of the rotors.

Letter windows
When the lid is shut, these windows allow the letters on the three wheels to be viewed.

Internal power switch
To create the current, this switch turns on the 4.5-volt battery inside the machine.

Entry wheel
This wheel does not play a role in changing the letter, but connects the plugboard to the rotors to carry on the inputted letter.

Plugboard
Before any further coding is involved, a plugboard scrambles the initial message. Ten cables are used to pair up letters. This means that the letters the wires connect are swapped in the entered message. If you were to use one wire to connect B to O, the word BOOM could change to OBBM.

Central wheels
These three wheels each have all 26 letters of the alphabet on them. Their beginning setting can be changed, and with each letter typed, the rotor pattern changes. The first of these wheels rotates one place after each letter is typed. When this wheel has completed a full circuit, the second wheel rotates one place, and the same occurs in the third when the second wheel fully rotates.

©Illustration by Adrian Mann

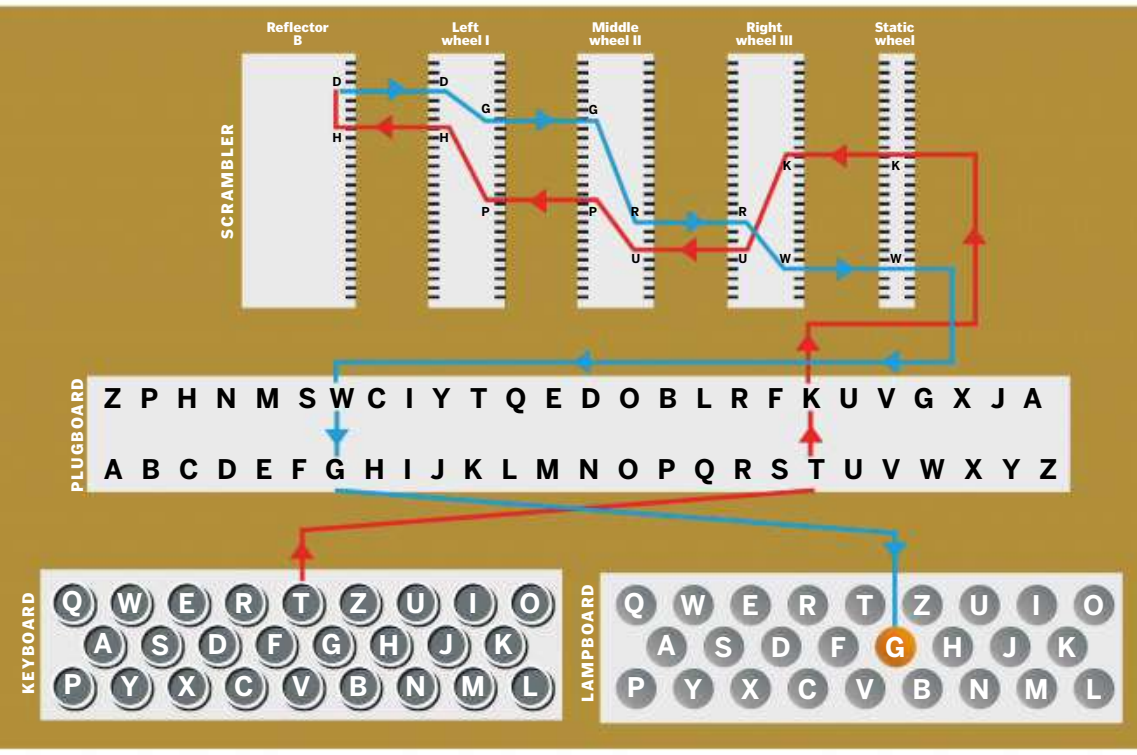
AR ZONE! SCAN HERE

Making a message

Each letter typed goes through nine encryption phases before emerging from the machine in its final form. Having so many conversions is what made this machine's mechanism so difficult to crack.

The rotors play a large part in generating random letters. After receiving a letter that has already been changed by the plugboard, the frequent and individual wheel turns make the pattern almost impossible to guess.

Each of the three wheels is wired differently, meaning the input letter will match a different output letter on each wheel. As the signal navigates through the three ciphers, it reaches the reflector rotor as a new letter. This would be enough to create a scrambled message, but only half of the coding is done. The reflector has its own cipher and sends the output letter back through the rotors. Then the signal gets a final change at the plugboard before lighting up as its final letter.


Reflector B
Left wheel I
Middle wheel II
Right wheel III
Static wheel
SCRAMBLER
PLUGBOARD
Z P H N M S W C I Y T Q E D O B L R F K U V G X J A
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
KEYBOARD
LAMPBOARD
Q W E R T Z U I O
A S D F G H J K
P Y X C V B N M L

THE RISE OF SUPER BUGS

How the widespread overuse of antibiotics is proving that too much of a good thing can be catastrophic

Antibiotics are without question the miracle drugs of the 20th century. Penicillin, the first widely produced antibiotic, saved more soldiers' lives during World War II than the Sherman tank. Since the 1940s researchers have discovered newer, more powerful strains of antibiotics to treat everything from a common ear infection to the most exotic tropical disease.

When a young mother or father takes their sick child to the doctor complaining of high fevers, green mucus and listlessness, they don't want to hear the standard speech about drinking lots of liquids and getting plenty of rest – they want something that will alleviate the symptoms almost instantly. They want to be given antibiotics. And sadly many doctors are more than happy to prescribe them, whether patients really need them or not.

According to the United States Centers for Disease Control, antibiotics are wrongfully administered in almost 50 per cent of cases. On an individual level there's no real harm in unnecessarily taking an antibiotic. However, widespread abuse of antibiotics has a potentially catastrophic effect on society as a whole. The more antibiotics that humans – and the animals we eat – take, the quicker bacteria evolve and the stronger they become. And what happens when bacteria evolve so significantly that our beloved antibiotics no longer have any effect on them?

Antibiotic resistance is one of the world's most serious health threats. We are already witnessing the rise of so-called 'superbugs', pathogenic bacteria that are immune to traditional antibiotic treatment. One of the best known superbugs is MRSA, short for methicillin-resistant *Staphylococcus aureus*.

Like several other drug-resistant bugs, MRSA spreads quickly through hospitals on the unwashed hands of health workers and patients. Staph infections are nasty enough. If allowed to enter the body they can target the lungs (pneumonia), the heart (endocarditis) and even the bloodstream (bacteraemia). MRSA is staph on steroids, because it has evolved to be resistant to the most effective antibiotics for

Pre-surgery antibiotics can prevent infection

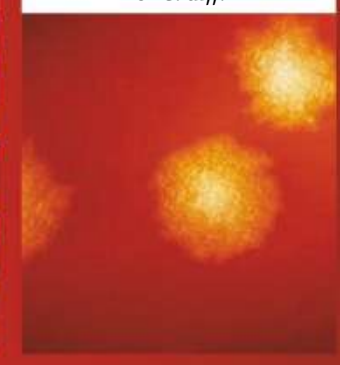
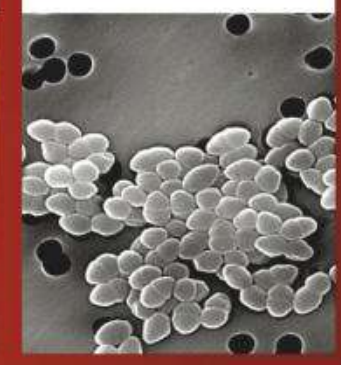
curing the infection. Imagine going into the hospital with a sprained ankle and leaving with a drug-resistant case of pneumonia.

So how do common bacteria like *S. aureus* and *E. coli* evolve so quickly from a curable annoyance to a potential pandemic? Let's start by dusting off our Darwin. Evolution by natural selection requires three things: reproduction, variety and selective pressure. Bacteria are masters of reproduction. Under the right conditions a bacterial colony will double in size every ten minutes. They do this through binary fission. Essentially the bacterium makes a copy of its own DNA, then splits in two. With so much copying and splitting, some mistakes – in the form of mutations – are going to be made. These genetic mutations increase the variety of traits that the bacteria can express. Variety is not only the spice of life, but also the engine of evolution.

When a doctor administers an antibiotic to kill off an infection of *S. aureus*, this applies a selective pressure to the bacterial colony. Bacteria that express beneficial traits – such as the ability to pump antibiotics out of their system – will survive, while the others will be wiped out. The surviving bacteria will then

TYPES OF SUPERBUG

Superbugs come in several flavours, all mutant variations of relatively common and even harmless bacteria that normally live in or on the human body. Fuelled by the overuse of antibiotics, these novel strains now have deadly potential

	Methicillin-resistant *Staphylococcus aureus* (MRSA)	Shiga toxin-producing *Escherichia coli* O104:H4	Drug-resistant *Clostridium difficile* NAP1 (*C. diff*)	Vancomycin-resistant Enterococci (VRE)
YEAR DISCOVERED	1960	EARLY 1990S	EARLY 2000S	1986
INFORMATION	While staph infections are common and usually curable with standard antibiotics, MRSA is stubbornly resistant to a family of antibiotics called beta-lactams. Most MRSA cases start as skin infections around wound sites, often exhibiting pus-filled boils. Life-threatening cases can involve blood infections, surgical site infections and pneumonia.	*E. coli* is transmitted to humans through food or water contaminated with animal faeces. Most cases can be treated with antibiotics, but the deadly strain O104:H4 is resistant to most major classes. In fact, antibiotic treatment triggers the release of toxins that make the symptoms – which include violent diarrhoea, kidney damage and blood clots – far worse.	Like MRSA, *C. diff* thrives in hospital settings and is resistant to many treatments. A *C. diff* infection is most often caused by prolonged antibiotic treatment. While antibiotics kill off unrelated infections, *C. diff* remains unharmed, colonising the gut and releasing a powerful toxin that causes colitis, severe diarrhoea and even perforation of the colon.	Enterococci bacteria live in the healthy human gut and female genital tract. But certain conditions can cause them to grow out of control, leading to urinary tract and even blood infections. The most powerful trigger is treatment with the antibiotic vancomycin. While this kills off harmful and healthy microbes, the Enterococci stay behind and thrive.
RESISTANT TO	Methacillin, oxacillin, penicillin, amoxicillin.	Eight classes of antibiotics including beta-lactams (penicillins), tetracycline and cephalosporins.	*C. diff* infections emerge after treatments with penicillins, clindamycin, cephalosporins and fluoroquinolones.	Vancomycin.
RISK ENVIRONMENTS	Shared spaces: hospitals, locker rooms, day care centres, university dorms, barracks and prisons.	Unwashed fresh fruits and vegetables pose the greatest risk of carrying the disease.	Hospitals. *C. diff* spores can live on contaminated surfaces for months.	Long-term hospital stays, especially with use of urinary catheters.
NUMBER OF DEATHS	19,832 deaths in the US in 2017; 292 deaths in England and Wales in 2012.	53 deaths in the 2011 European outbreak.	Five per cent mortality rate within 14 days of sample collection.	In 2017, 54,500 patients in US hospitals were infected, causing 5,400 deaths.
TREATMENT	Cleaning, incision and drainage of the wound. Testing to determine bacteria type and use of a targeted antibiotic.	Hydration, pain relief and close monitoring for severe symptoms like kidney failure or blood clots.	It can resolve itself a few days after antibiotic treatment ends. Others will need a stronger course of antibiotics like metronidazole.	Lab tests will indicate which antibiotics other than vancomycin can be used to treat the infection.
PREVENTION	Avoid skin-to-skin contact with hospital patients or others with open wounds. Wash hands thoroughly after hospital visits, trips to the gym and so on.	Thoroughly wash fruits and vegetables and fully cook all meat and poultry products before eating.	Ensure hospital staff wash hands before touching you or your food. Transmission by healthcare workers is the number one transmission method for *C. diff*.	Better hospital sanitation, limited use of antibiotics and frequent changing of catheters.
				

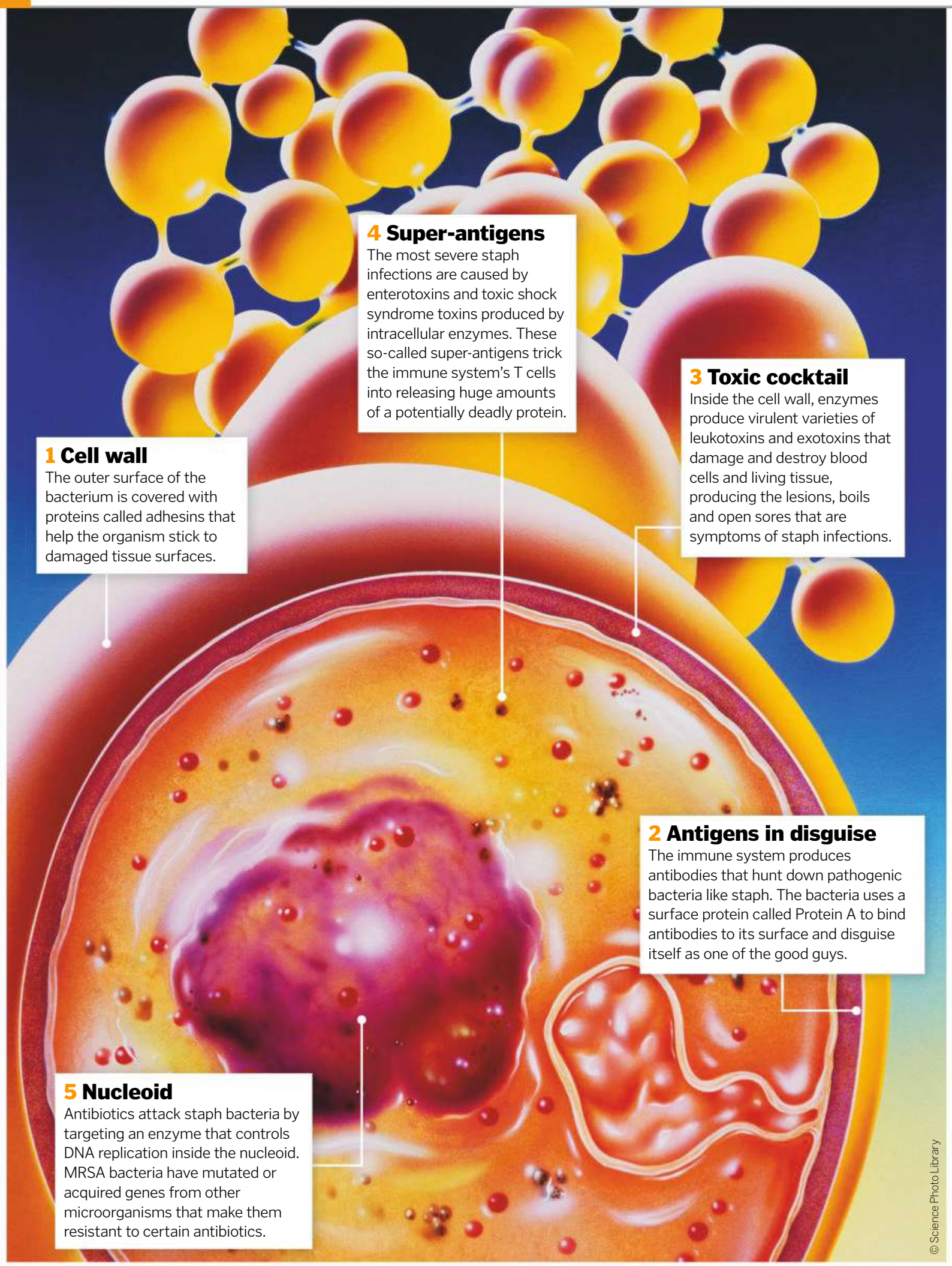
repopulate the colony, and the next time the antibiotic is applied, it will be completely useless.

Bacteria are not only evolutionarily efficient, they are also cheaters. Through a process called conjugation, two bacteria can share slices of genetic material that carry beneficial traits, skipping the randomness of natural selection altogether. By this method, some bacteria have developed techniques for disguising themselves to antibiotics, blocking the entrance to the cell wall and even tricking the body's own immune system to release toxic levels of proteins.

The best weapon against the spread of superbugs is to reduce our overall consumption of antibiotics – including the beef, pork and dairy industries, which are responsible for administering approximately 80 per cent of the antibiotics in America – and to improve hygiene and sanitation at hospitals, where these infections thrive and spread.

Inside an MRSA bacterium

MRSA is a drug-resistant strain of *Staphylococcus aureus*, one of the most virulent and violent bacteria we know. Staph infections come in all flavours, from diarrhoea-inducing food poisoning, to skin lesions, to potentially fatal cases of toxic shock syndrome. MRSA is a staph bacterium that has mutated or otherwise acquired genetic traits that defend it against attacks from antibiotics.



1 Cell wall
The outer surface of the bacterium is covered with proteins called adhesins that help the organism stick to damaged tissue surfaces.

4 Super-antigens
The most severe staph infections are caused by enterotoxins and toxic shock syndrome toxins produced by intracellular enzymes. These so-called super-antigens trick the immune system's T cells into releasing huge amounts of a potentially deadly protein.

3 Toxic cocktail
Inside the cell wall, enzymes produce virulent varieties of leukotoxins and exotoxins that damage and destroy blood cells and living tissue, producing the lesions, boils and open sores that are symptoms of staph infections.

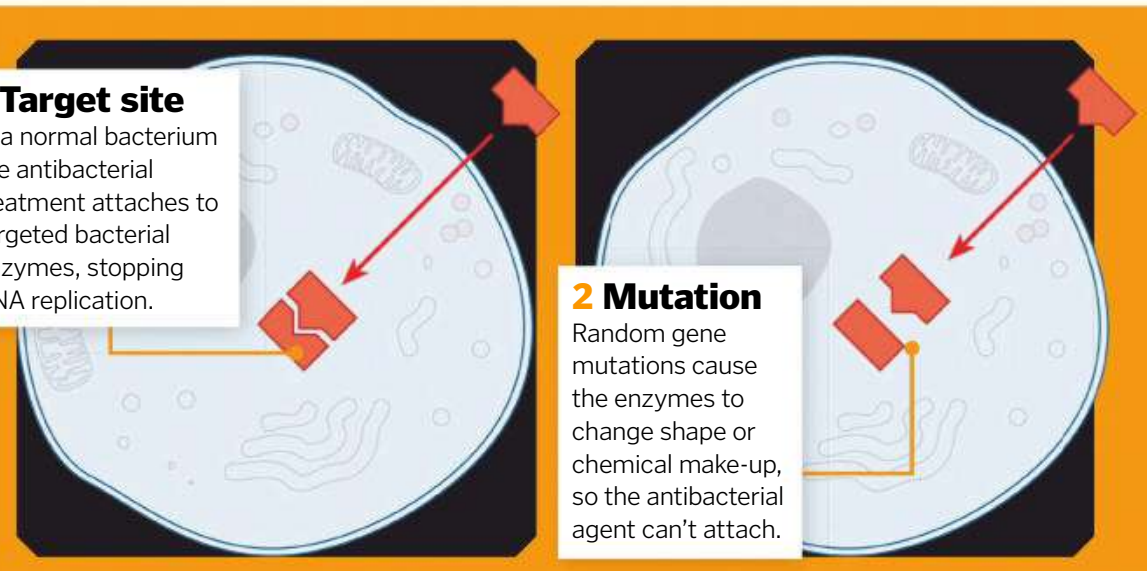
2 Antigens in disguise
The immune system produces antibodies that hunt down pathogenic bacteria like staph. The bacteria uses a surface protein called Protein A to bind antibodies to its surface and disguise itself as one of the good guys.

5 Nucleoid
Antibiotics attack staph bacteria by targeting an enzyme that controls DNA replication inside the nucleoid. MRSA bacteria have mutated or acquired genes from other microorganisms that make them resistant to certain antibiotics.

© Science Photo Library

Why antibiotics don't work

Bacteria exist in our bodies by the billions. Some 1,000 different species live in the human gut alone. With such a large and thriving population, it's easy to understand how a few bacteria might randomly acquire traits that make them more resistant to 'killer' drugs like antibiotics. Through Darwinian evolution the strongest, most resistant bacteria survive. Bacteria acquire these resistant traits through two mechanisms: genetic mutations or by genetic transfer from other organisms. These new traits effectively block antibiotic particles from reaching their target enzymes inside the bacterial cell wall.



1 Target site
In a normal bacterium the antibacterial treatment attaches to targeted bacterial enzymes, stopping DNA replication.

2 Mutation
Random gene mutations cause the enzymes to change shape or chemical make-up, so the antibacterial agent can't attach.

Superbugs and hospitals

For bacteria, a hospital is like an evolutionary experiment gone mad. Think about how many antibiotics are prescribed in a hospital. And think about the broad range of pathogenic bacteria that walk through the door on the skin and in the mouths, noses, ears and open wounds of patients. Even after we bomb these bacteria with drugs, a few hardy mutants will survive. These germs pass easily from patient to patient on unwashed hands and contaminated surfaces. A healthy patient might come in for a couple of stitches and leave with a raging, drug-resistant infection.

© Kurhan

Healthcare workers

Skin-to-skin contact is the most effective way to spread a superbug. Health workers must wash hands between patients and before leaving a patient's room.

Isolation and cohorts

Patients who are known to be MRSA positive should be isolated from the general population, and special precautions should be taken by healthcare workers and visitors. Several MRSA patients can be bedded together as a cohort.

Catheters and IVs

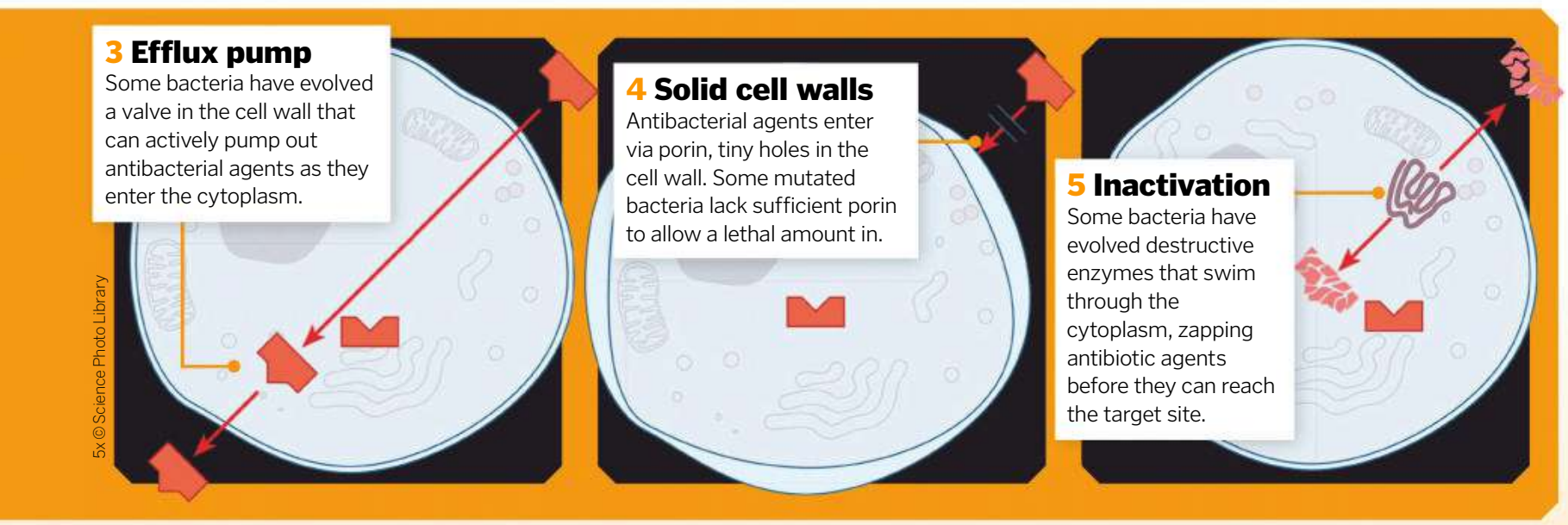
Health workers need to take particular care when inserting catheters or IVs. MRSA skin infections can easily pass into the urinary tract or bloodstream if proper hygienic precautions aren't taken.

Surface contamination

Studies have shown that hospital surfaces like computer keyboards, tap handles, pens and doctors' scopes contain surprisingly high levels of pathogenic bacteria.

Gloves and scrubs

To further reduce the transmission of superbugs on skin and clothing, some hospitals are requiring the use of disposable gloves and temporary clothing like scrubs in high-risk areas.



3 Efflux pump

Some bacteria have evolved a valve in the cell wall that can actively pump out antibacterial agents as they enter the cytoplasm.

4 Solid cell walls

Antibacterial agents enter via porin, tiny holes in the cell wall. Some mutated bacteria lack sufficient porin to allow a lethal amount in.

5 Inactivation

Some bacteria have evolved destructive enzymes that swim through the cytoplasm, zapping antibiotic agents before they can reach the target site.

5x © Science Photo Library

TEN TIPS TO PREVENT THE SPREAD OF SUPERBUGS

1 Recognise that the overuse or misuse of antibiotics is a major cause of increasing antibiotic resistance.

2 Understand that antibiotics can only cure bacterial infections, not viral infections like colds or the flu.

3 Never take leftover antibiotics that you find in your house.

4 When prescribed antibiotics, follow your doctor's instructions and take the full course, which is usually the entire bottle.

5 Never take antibiotics prescribed to a friend just because you have the same symptoms as them.

6 Unless your symptoms are severe, take the time to have tests taken to determine the exact bacterial pathogen that's affecting you. This will allow your doctor to prescribe a targeted antibiotic instead of a wider spectrum treatment.

7 Even if you and your doctor feel that you probably have an infection, ask about alternative treatments and remedies that might resolve the infection without the use of antibiotics.

8 Support farms and dairies that don't use prophylactic antibiotic treatments to stave off infections among their animals. Overuse of agricultural antibiotics is one of the greatest causes of antibiotic resistance.

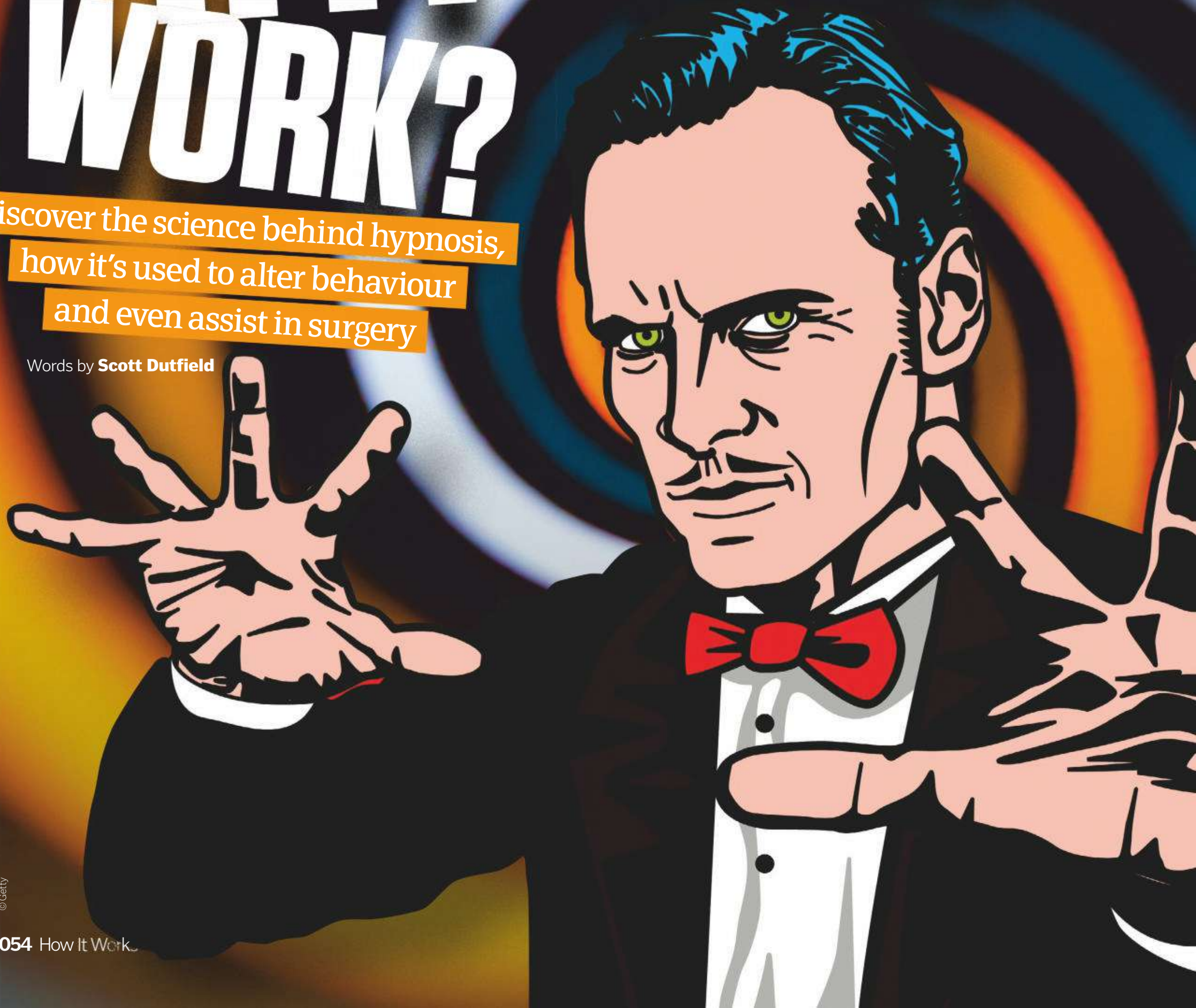
9 Don't use low-level antibiotics to resolve chronic acne. Try other methods instead.

10 Healthcare professionals and hospital visitors must be vigilant about hand washing and overall sanitation, particularly when around patients who are immuno-compromised.

HOW DOES HYPNOSIS WORK?

Discover the science behind hypnosis, how it's used to alter behaviour and even assist in surgery

Words by **Scott Dutfield**



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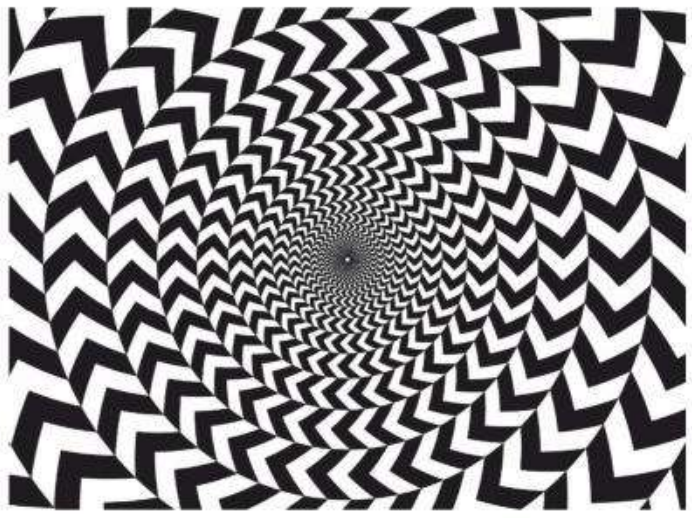
It makes for some lighthearted entertainment when a group of willing volunteers walk on stage and stare blankly at a swinging pocket watch before remarkably transforming into a group of clucking chickens, but is hypnosis more than just a stage show?

Hypnosis is by no means a modern-day technique, with the first recorded medical use described in the Egyptian Ebers Papyrus, which was written in about 1550 BCE. Over time the skill of sending people into a deep trance has evolved to tap into the subconscious and implant suggestions to change addictive behaviours or treat ailments.

However, much like many other aspects of how the brain works, scientists remain relatively baffled by the phenomenon of hypnosis. It is collectively understood that its success is based on a person entering a heightened state of relaxation and focus through verbal and visual guides, at which point it's believed that our brains are more susceptible to suggestion. There are two main theories as to why this works and what it does to our brains. Altered-state theory explains that hypnosis is much like sleep in the sense that when in a trance-like state the brain's processes work differently, although you are not awake to acknowledge them. The non-state theory suggests that a hypnotised person is still aware of what's happening, unlike when you're asleep, and they are actively participating in the hypnotist's instructions. However, there is still some debate and uncertainty behind which theory is correct.

So how do you become hypnotised? In a nutshell, a hypnotist or hypnotherapist 'induces' a person into a state of relaxation using verbal suggestion, typically using some sort of sleep analogy. After placing more and more emphasis on their imagination about something that is not in their real environment, a person begins to enter into a hypnotic state. However, not everyone is susceptible to hypnosis. A person's 'hypnotisability' can range from them being completely immune and unresponsive to any hypnotic technique to a small percentage of the population being highly hypnotisable and susceptible to suggestion. Those that are highly responsive to hypnosis have shown that the technique can be used during surgery. Some patients have even been known to respond to posthypnotic suggestions, whereby an instruction will be given for an action to be carried out years later.

As a method of therapy, those within the extreme limits of hypnotisability can benefit from the well-documented advances in treating problematic behaviours such as smoking, or the treatment of obesity and anxiety. Hypnosis is much more than a theatrical performance we can see on stage – it can be a rather useful medical tool.



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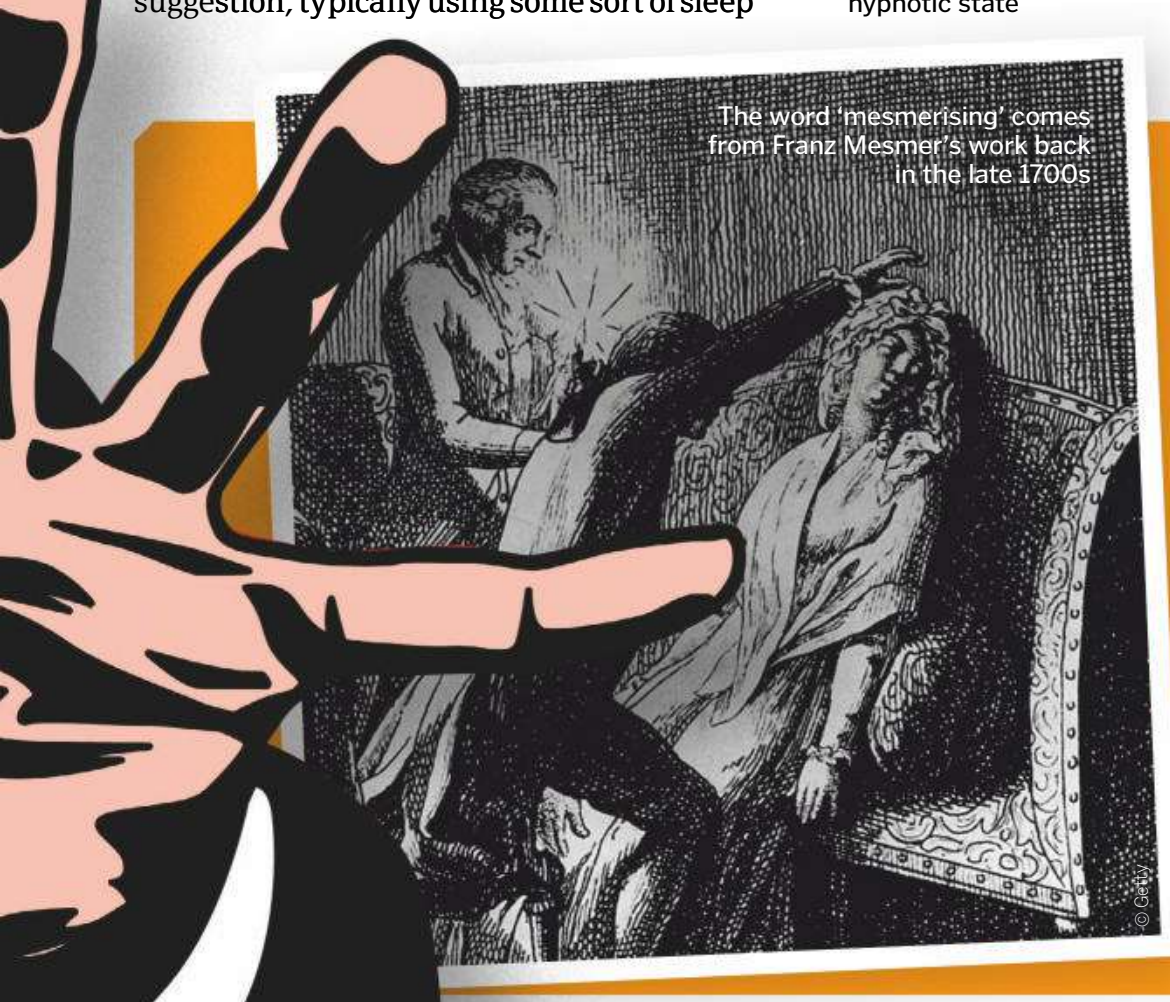
Visual guides are often used to lure people into a hypnotic state



The word 'mesmerising' comes from Franz Mesmer's work back in the late 1700s

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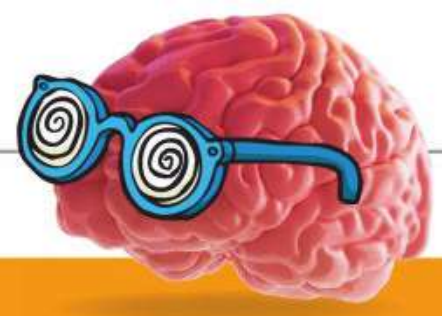


Stages of hypnosis

There's a host of different techniques used to induce a trance during hypnotherapy

Priming

This is where the hypnotherapist may prepare or outline the patient's trance. This may involve carrying out an interview about the goals of the treatment.

Preparation

The patient is placed in a comfortable position with their eyes closed. Breathing techniques may then be used to help relax the patient.

Induction

Hypnotic induction involves one of several techniques. The patient may be guided into a meditative state through calming visual cues, such as imagining a beach.

Hypnotic state or trance

Following a successful induction the patient will enter a state of heightened relaxation, both physically and mentally.

Suggestion

Intended to replace or edit subconscious thoughts, a hypnotherapist will use verbal communication to make suggestions to alter behaviour.

Emergence

A cue set by the hypnotherapist in the priming stage – such as a sound or word – may be used to bring the patient out of their trance-like state.

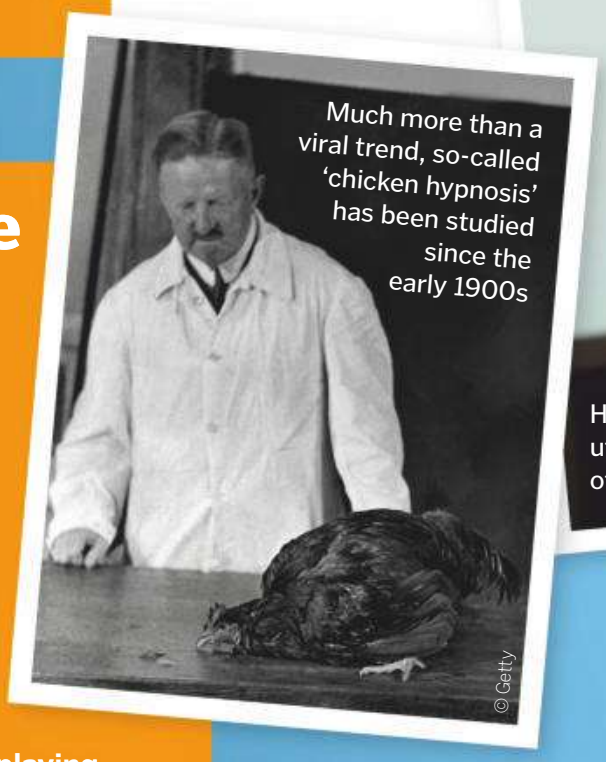
© Getty

The invention of hypnotherapy

Staring deep into the eyes of his patients, Franz Anton Mesmer, a German physician, took Europe by storm with his claims of curing ailments using what was then thought to be a new science: animal magnetism. In the late-18th century, Mesmer believed that the body was surrounded by a magnetic 'fluid', and with the aid of a magnet or an individual thought to have a 'higher natural magnetic force', such as himself, he could alter the fluid and thus relieve the patients of their issues, all while putting them into a suggestive mental state. Word spread about Mesmer's technique – now known as 'mesmerism' – throughout Vienna, where he lived. However, so did rumours that the treatment was ineffective and had been disproved by his peers. As more and more people heard of the Mesmer scandal, he fled to Paris to continue his work of fraudulent mesmerism once again. Having built a new reputation, Mesmer secured high-profile clients, including royalty when Queen Marie Antoinette called upon his services. However, once again the scandal of his inaccurate science caught up with him, forcing him to travel around the rest of Europe before dying in Germany in 1815. Although Mesmer's theory of animal magnetism was fraught with inaccuracy, he did get one thing right: the suggestive mental state he induced in his patients went on to be the basis for the effective hypnosis we see today.

Can animals be hypnotised?

You may have seen videos online in which a seemingly alert chicken is held on the ground and a line is drawn moving away from its beak. When directed to look at the line the chicken suddenly stops in its tracks. Appearing to be fixated and motionless as if under a hypnotic trance, is the chicken truly hypnotised? The chicken isn't actually hypnotised, but is displaying what scientists call tonic immobility, a fear-potentiated response. It's thought that the chicken believes its life is in danger due to the unfamiliar stress of being restrained and held to the ground. Focusing the chicken's attention in this way while pinning it down sends the chicken into a catatonic state, making it appear paralysed. Animals such as ducks, sharks, snakes and rabbits all display this behaviour to avoid predators, almost like playing dead.



Much more than a viral trend, so-called 'chicken hypnosis' has been studied since the early 1900s

© Getty

Hypnosis can be utilised as a form of therapy

© Getty

Under the hypnotic knife

Although it's safe to say we're unlikely to see open-heart surgeries or transplants carried out solely with hypnotic pain alleviation, there are plenty of examples of hypnosis managing pain during less invasive procedures. In 2014 Alama Kante, a Guinean singer based in Paris, underwent surgery to remove a parathyroid gland tumour from her throat. Although this wasn't a life-threatening condition, without treatment the singer's career may have come to an end. A world first at the time, Kante underwent the surgery without anaesthesia and instead entered a hypnotic trance-like state during the procedure. This would allow her to sing during the critical moments of the surgery so that the surgeons could make sure that they did not damage her vocal cords. The surgery was a success, while Kante was blissfully unaware as she envisioned far-away Senegal.

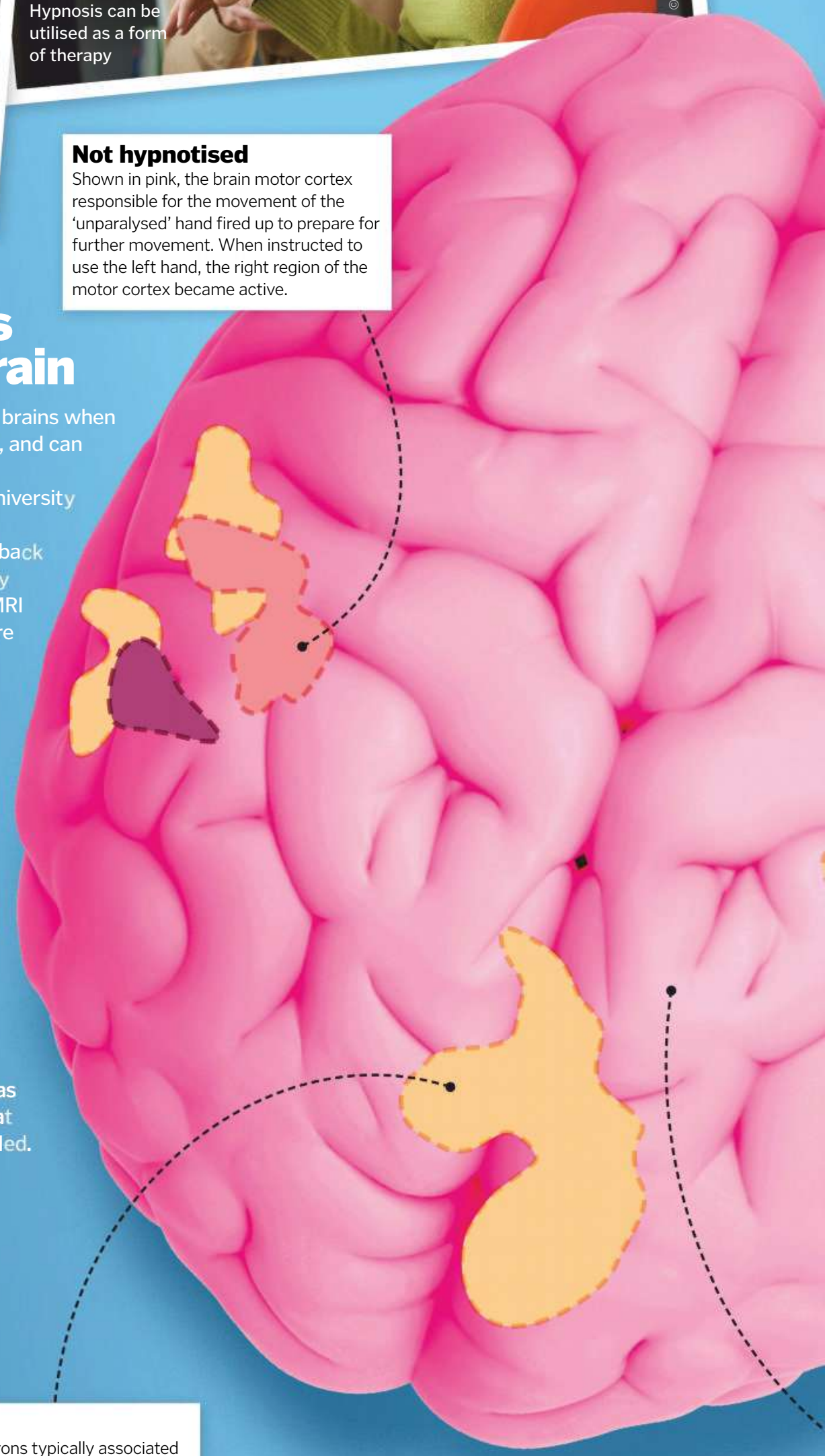
© Alamy

Hypnosis has been used during a wide range of surgeries, including a caesarean birth

Hypnosis on the brain

What happens to our brains when we undergo hypnosis, and can you see its effects? Researchers at the University of Geneva put these questions to the test back in 2009. Placing study participants into an MRI scanner, subjects were asked to press a button with either their right or left hand when instructed while snapshots of their brains were taken. However, some of the participants had been instructed through hypnosis that their left hand was 'paralysed', while others were not, and a small group was asked to pretend their hand was paralysed. Here's what the brain scans revealed.

- HYPNOTISED
- UNHYPNOTISED
- UNHYPNOTISED & PRETENDING



Not hypnotised
Shown in pink, the brain motor cortex responsible for the movement of the 'unparalysed' hand fired up to prepare for further movement. When instructed to use the left hand, the right region of the motor cortex became active.

Hypnotised
Shown in yellow, the neurons typically associated with motor skills, such as moving the arms, fired up. However, following the suggestion that the left hand was paralysed, these neurological signals failed to reach the region of the brain responsible for movement and were instead directed to the posterior region of the brain called the precuneus.

"Hypnosis is much more than a theatrical performance we can see on stage"

Pretending
When only pretending to have been paralysed by hypnotic suggestion the redirection of brain signals seen in those who had been hypnotised did not occur and the regions of the brain that became active followed those who were not hypnotised, shown in purple.

This area of the brain is responsible for our ability to visualise memories and is thought to play a part in our self-consciousness – the awareness of yourself. It's believed that the reason this area of the brain is fired up is due to the visualisation of the hypnotic suggestion that the left hand is too heavy to lift and therefore paralysed.

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© Deirdre Barrett

Could you be hypnotised?

As an assistant professor of psychology at Harvard University and the author of *The Pregnant Man and Other Cases from a Hypnotherapist's Couch,* Deirdre Barrett gives us an insight into the benefits of hypnosis and who might be susceptible to hypnotic suggestion

Are there any factors which determine whether you're more or less susceptible to hypnosis?

Yes. There's a little bit of research that suggests it may have some biological element. Identical twins seem to have some correlation between their hypnotic susceptibility. We certainly think that a lot of it is learned behaviour or just variables that we don't completely understand. Susceptibility or absorption – meaning absorption in imaginative involvement – questionnaires are the best predictors. They are basically questions that have to do with experiencing informal trance-like phenomena at other times, such as did you ever have an imaginary companion as a child? When you imagine something, can you picture it very vividly? When you are focused on reading a novel, does someone have to call your name much more loudly or repeatedly before you hear them?

It's about vivid imagination and about tuning out the real environment or sometimes experiencing physiologic sensations such as queasiness, cold or hotness as somebody suggests them or you're looking at a visual stimulus about them. That sort of scale predicts response to a formal hypnotic induction quite well. People may not realise quite how much they can do this, but in a sense they're already tending to do that sort of thing to informal suggestions, and the ability is manifesting itself in everyday life in milder ways.

Why do people forget what's happened during the time they are hypnotised?

Most people do remember what's happened. If the hypnotist suggests that you will not remember anything, the average person will remember. It's people in the top ten per cent of hypnotisability that are able to have suggested amnesia. It's an even smaller group that seems to have spontaneous amnesia, and of those you can hypnotise a person and suggest that they'll now recall what happened. Then there are a few people that just never recall, and yet presumably something was registering.

People sometimes have psychologically caused amnesia to very traumatic sudden events. There are psychological disorders in which people don't remember certain kinds of material, so it's something that the human brain is capable of, but that we don't usually have on-demand control over.

How effective is hypnosis in treating lifelong behavioural issues such as smoking?

Hypnosis is a really dramatically effective treatment for people who are highly hypnotisable. It's really having no more than a bit of a placebo effect for people of low hypnotisability. For things like habit changes, there are two things that predict how well the treatment will go, and one of them is how hypnotisable the person is, but also motivation, how badly the person wants to quit, how willing they are to apply willpower to this. There may be some people who go into a very light trance and only get a bit of help in resisting urges to smoke, but are nevertheless very motivated in the general sense, who will then quit smoking. However, for the high hypnotisables you really get to tune out the physiologic withdrawal. Just like with pain control, it doesn't do anything dramatic for most people, but you can tune out extreme pain if you're a high hypnotisable. I have worked with and seen high-hypnotisable patients who were lifelong smokers who after one session just said they had no desire to smoke. They reported disgust at cigarettes and no cravings.

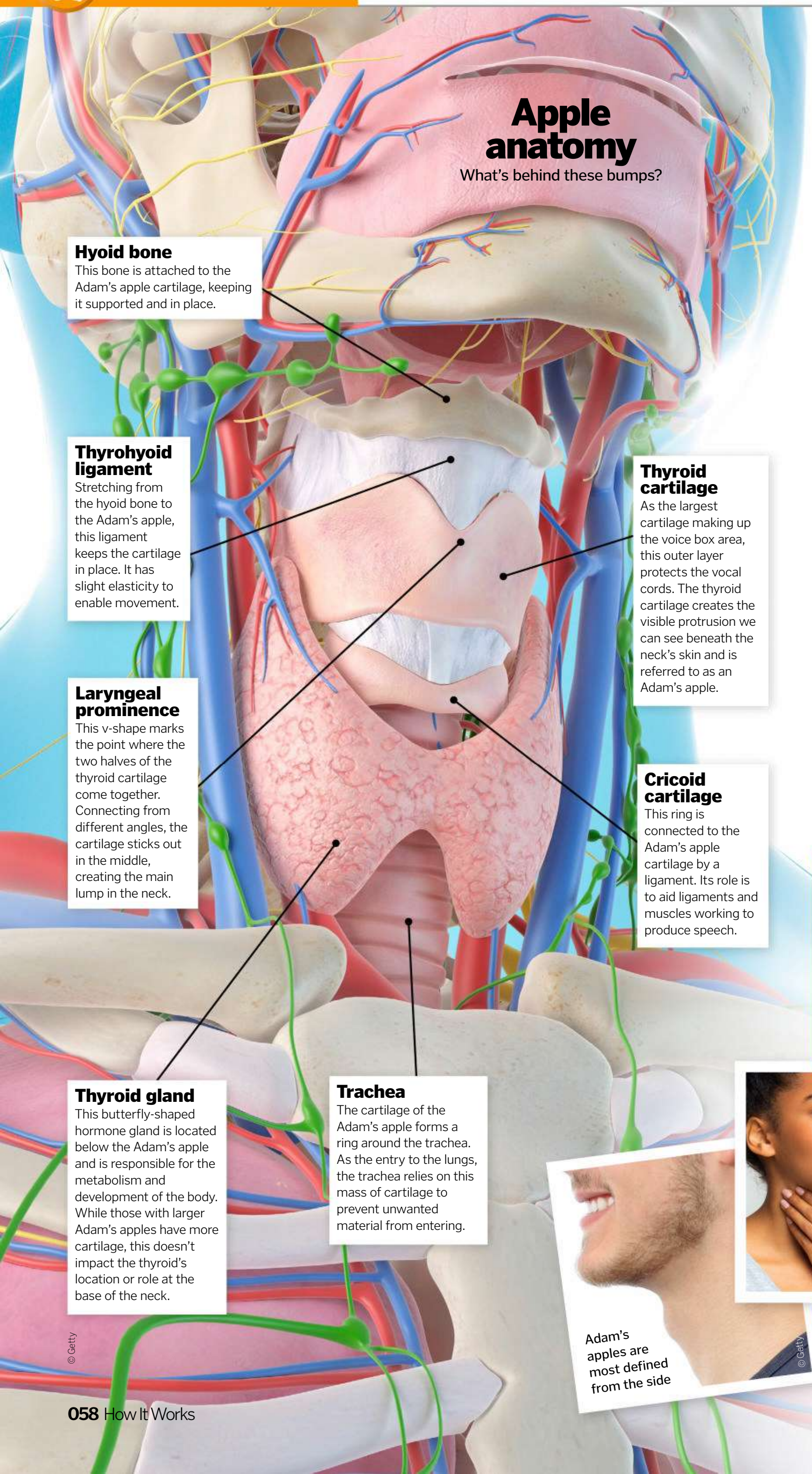
What are Adam's apples?

These permanent lumps in our throats contain a crucial organ

Some people have noticeable bumps sticking out from the front of their throats, usually men. While everybody has one, not all can be seen. Apart from dancing along the neck as you speak, what is the point of this feature?

The Adam's apple, named because it looks like a piece of food stuck in the throat, starts to emerge during puberty. The lump in the neck that develops is cartilage under the skin, responsible for protecting our voice box, known as the larynx. The bigger the voice box is, the larger the protective covering needs to be.

Because an Adam's apple encases the vocal cords, they can be seen moving up and down in time with speech. When it lifts in the neck, this is a sign that the cartilage is closing the throat. These movements can also be observed when swallowing, or even as a tell-tale sign of feeling nervous.


Apple anatomy
What's behind these bumps?
Hyoid bone
This bone is attached to the Adam's apple cartilage, keeping it supported and in place.
Thyrohyoid ligament
Stretching from the hyoid bone to the Adam's apple, this ligament keeps the cartilage in place. It has slight elasticity to enable movement.
Thyroid cartilage
As the largest cartilage making up the voice box area, this outer layer protects the vocal cords. The thyroid cartilage creates the visible protrusion we can see beneath the neck's skin and is referred to as an Adam's apple.
Laryngeal prominence
This v-shape marks the point where the two halves of the thyroid cartilage come together. Connecting from different angles, the cartilage sticks out in the middle, creating the main lump in the neck.
Cricoid cartilage
This ring is connected to the Adam's apple cartilage by a ligament. Its role is to aid ligaments and muscles working to produce speech.
Thyroid gland
This butterfly-shaped hormone gland is located below the Adam's apple and is responsible for the metabolism and development of the body. While those with larger Adam's apples have more cartilage, this doesn't impact the thyroid's location or role at the base of the neck.
Trachea
The cartilage of the Adam's apple forms a ring around the trachea. As the entry to the lungs, the trachea relies on this mass of cartilage to prevent unwanted material from entering.
If you can't see your Adam's apple, you can find it by holding your neck and swallowing
Adam's apples are most defined from the side
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Just for men?

A common misconception is that only men have Adam's apples, but they are actually a part of every person's anatomy. This being said, in most instances it is a more prominent feature in men.

The reason is to do with the voice of the person. Grown men have often developed deeper voices, which are a product of larger voice boxes. Due to their larynx's larger size, the Adam's apple covering it sticks out further.

It is important to realise it is normal for men and women's voice boxes to vary. Many women have pronounced Adam's apples and many men have them hidden away.

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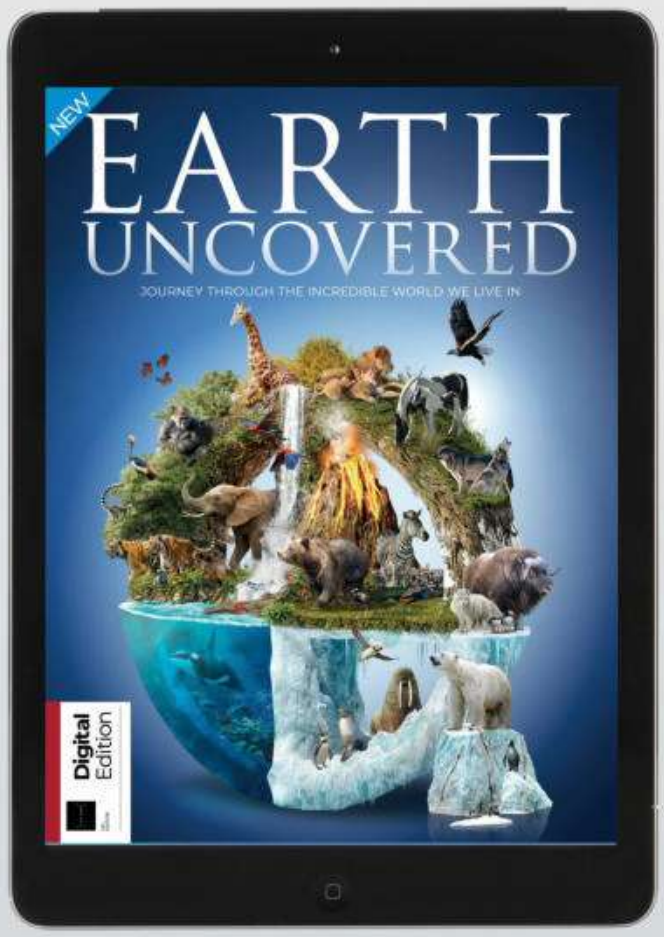
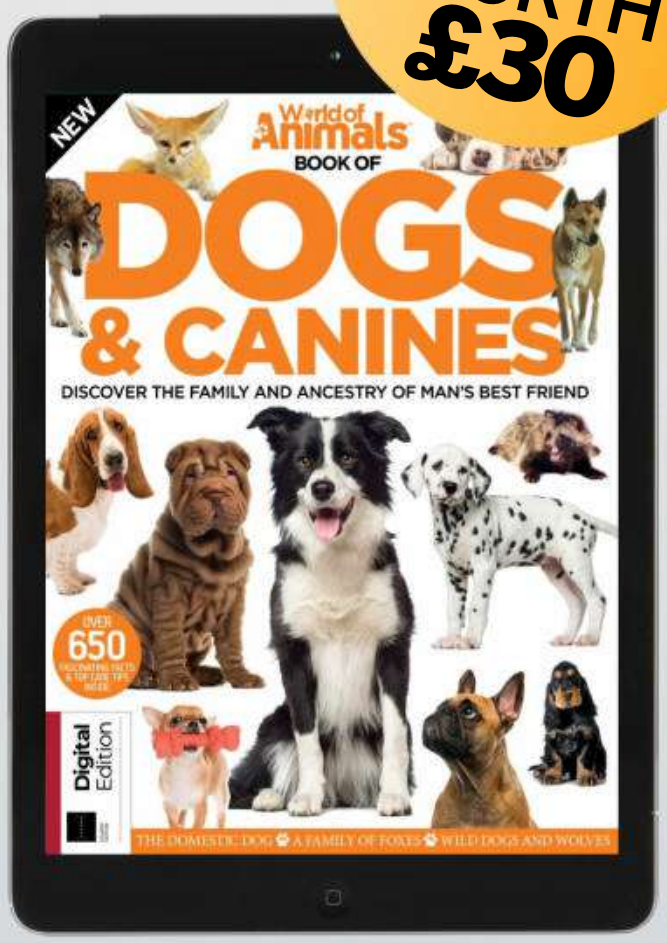
Book of Robots

As machines perform more and more functions than we ever imagined, they become ever more present in our lives. Trace the history of the first robots and discover the best bots that you can own right now. Gaze into the future of robotics and look closer to home at those designed to make your house smart. Discover how robots are helping us find new worlds before meeting the megabots who fight for sport. Finally, learn to make your very own robot using a simple Raspberry Pi kit and some code.



Earth Uncovered

Join us as we journey across the incredible world we live on, exploring its awesome landscapes, weather wonders, geological marvels and diverse wildlife. Learn about extreme landscapes such as Antarctica, the Amazon rainforest and the African savannah, as well as features such as mountain ranges, meandering rivers, desolate deserts and coral reefs. Filled with breathtaking imagery and awe-inspiring facts, there is something for everyone in this stunning book.



Book of Dogs & Canines

There is no better friend in life than a dog. But while we don't pay a second thought to inviting chubby chows into our homes or letting our senior spaniels sleep in our bed, we often forget their predator origins. Its ancestor the wolf is part of a large canine family, along with jackals, dingoes and foxes. This book explores all the different canids, from the ones that chew our shoes to the ones that could crush our bones. Flip the page if you dare, and discover the cuddly and cut-throat world of dogs.

Claim yours here: **bit.ly/30HapHS**

Mercury

Compared to the other planets, we know relatively little about the smallest planet in our Solar System

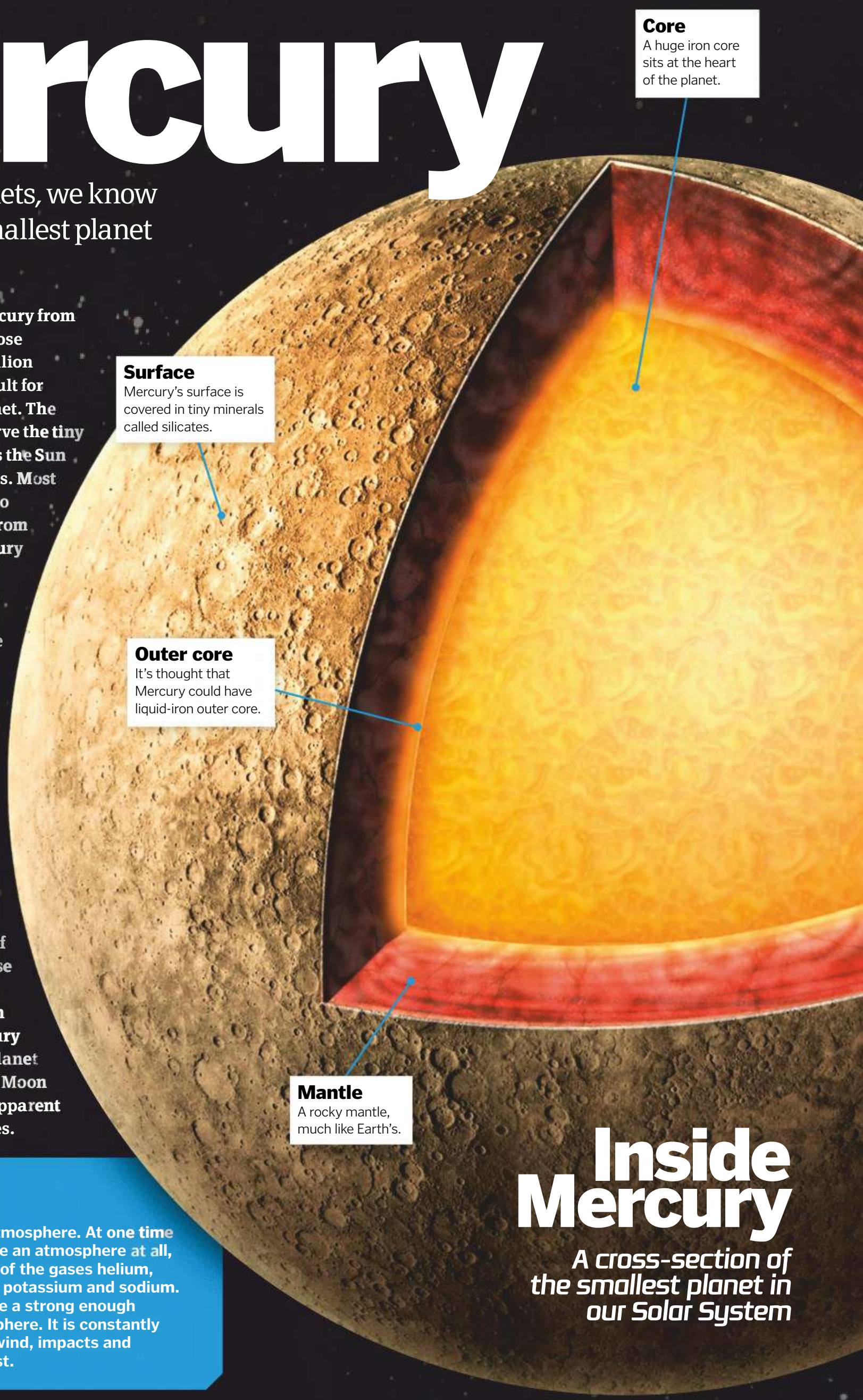
Although we've been observing Mercury from Earth for thousands of years, its close proximity to the Sun – about 58 million kilometres on average – has made it difficult for astronomers to learn much about the planet. The Hubble Space Telescope is unable to observe the tiny planet because turning that close towards the Sun would damage the telescope's instruments. Most of what we know came from the Mariner 10 space probe's flybys in 1974 and 1975 and from NASA's MESSENGER, which orbited Mercury between 2011 and 2015. Europe's BepiColombo spacecraft will gather more data on the planet when it arrives in 2025.

With the naked eye Mercury can only be seen at dawn or dusk – depending on the time of year. Mercury can also be seen as a small black spot moving across the Sun at intervals of seven, 13 and 33 years. This is known as a transit of Mercury, and occurs when the planet passes directly between Earth and the Sun.

Mercury has the shortest year of any planet at 88 Earth days. It orbits around the Sun faster than any other planet, which is why it was named after the speedy Roman messenger god. Conversely, Mercury has the longest day of any planet due to its slow rotation. Because it revolves so quickly around the Sun, yet only rotates on its axis once every 59 Earth days, the time between sunrises on Mercury lasts 176 Earth days. Mercury is also the planet that has the most eccentric orbit. Like our Moon Mercury can be observed going through apparent changes in its shape and size called phases.

Atmosphere

Mercury has a very thin almost-airless atmosphere. At one time it was believed that the planet didn't have an atmosphere at all, but it does contain small concentrations of the gases helium, hydrogen and oxygen as well as calcium, potassium and sodium. Because of Mercury's size, it doesn't have a strong enough gravitational pull to keep a stable atmosphere. It is constantly being lost and replenished via the solar wind, impacts and radioactive decay of elements in the crust.

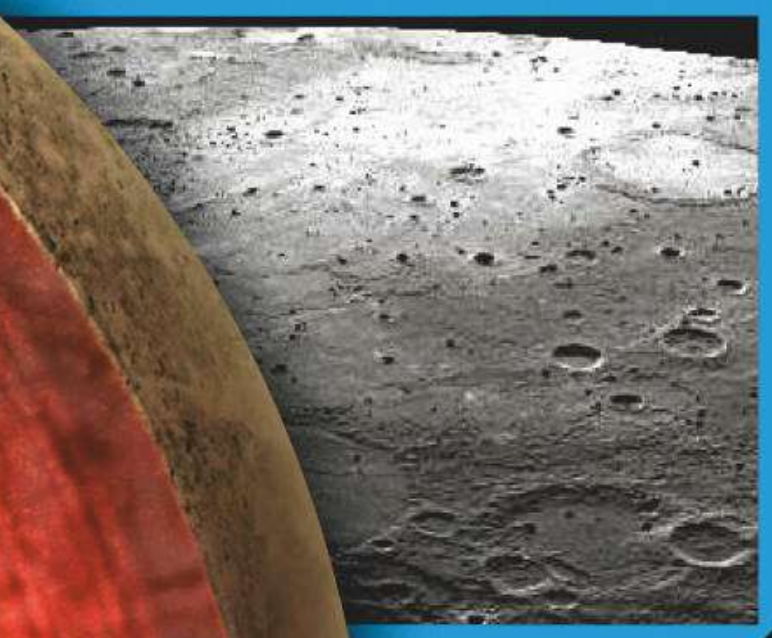

Core
A huge iron core sits at the heart of the planet.
Surface
Mercury's surface is covered in tiny minerals called silicates.
Outer core
It's thought that Mercury could have liquid-iron outer core.
Mantle
A rocky mantle, much like Earth's.

Inside Mercury

A cross-section of the smallest planet in our Solar System

Terrestrial planet

Like Earth, Mercury is a rocky planet. It comprises about 70 per cent metal and 30 per cent silicate materials. Because Mercury is so dense – almost as dense as Earth, although it's much smaller – it probably has a very large iron-rich core. Scientists believe that Mercury's core makes up almost half of the planet's total volume and three-quarters of its total radius. It also contains more molten iron than any other major planet in the Solar System. The core is estimated to have a radius of about 1,800 kilometres, with a mantle about 600 kilometres thick and a crust about 35 kilometres thick. There are a few potential explanations for this large core. Mercury may have had a more substantial crust and mantle that were stripped away by high temperatures and solar wind from the Sun, or it could have been hit by a still-forming planet called a planetesimal.



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The statistics

Mercury

Diameter: 4,879 kilometres
Mass: 3.3010 × 10^{23} kilograms
Density: 5.427 grams per cubic centimetre
Average surface temperature: 167°C
Average distance from the Sun: 57,910,000 kilometres
Surface gravity: 0.38 g

Caloris Montes

Mercury has several mountains, known as montes, the tallest and largest of which are the Caloris Montes. This is a series of circular mountain ranges up to three kilometres in height located on the rim of the huge Caloris basin. The Caloris Montes are massifs formed when Mercury's crust flexed and fractured due to impact.

Temperature extremes

Temperatures on the planet fluctuate wildly depending on the location on the planet, the time of day and how close Mercury is to the Sun in its orbit. At night surface temperatures can go down to -180 degrees Celsius. During the day they can reach 430 degrees Celsius. Some scientists believe that ice may exist under the surface of deep craters at Mercury's poles. Here temperatures are below average because sunlight cannot penetrate.

Moon-like surface

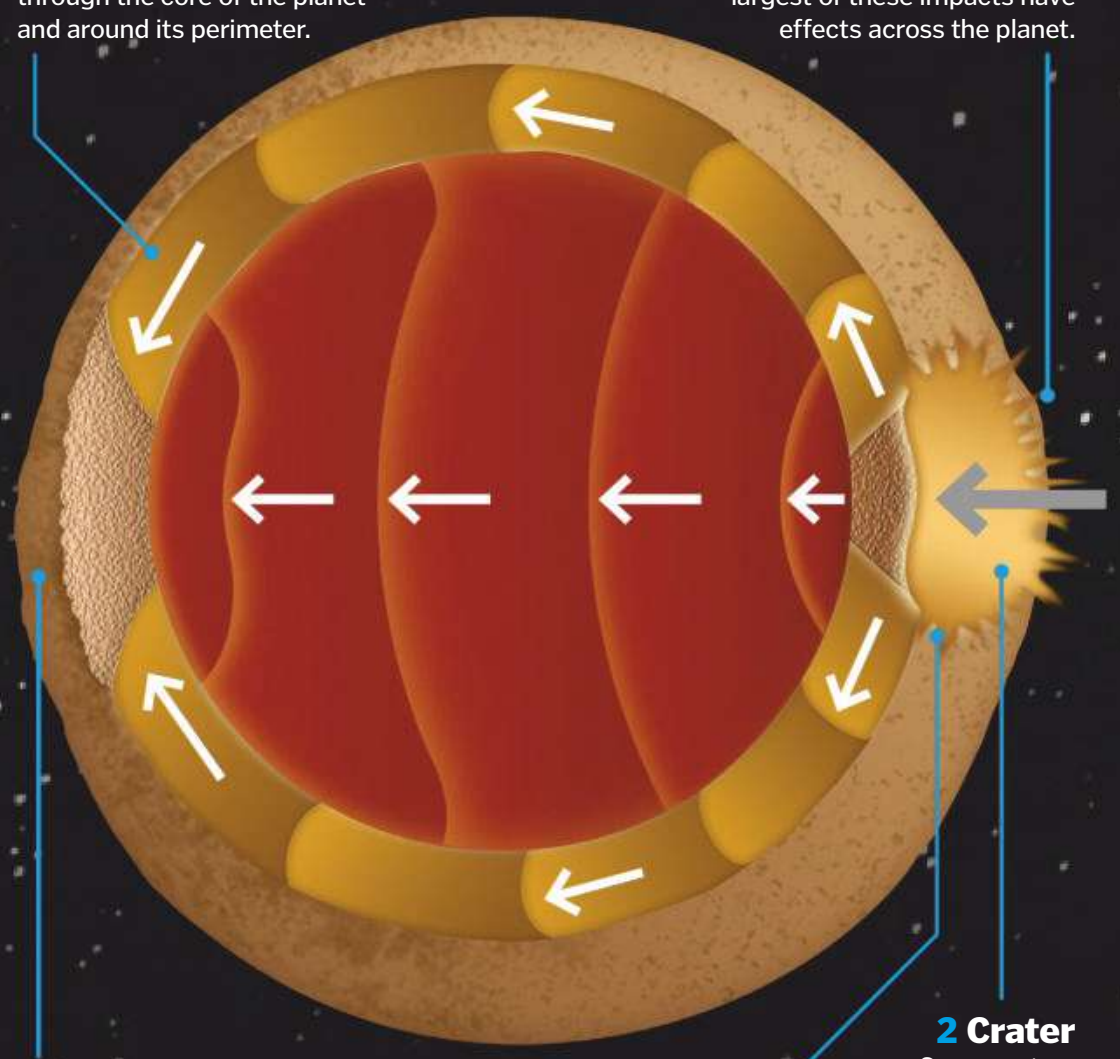
The surface of Mercury looks much like the surface of our Moon. The largest crater on Mercury is the Caloris basin at 1,550 kilometres across. The impact that formed it caused lava eruptions and shock waves that formed hills and furrows around the basin. Mercury also has two different types of plains. The smooth plains were likely formed by lava flows, while inter-crater plains may have been formed by lava or by impacts. The most unusual features are the wrinkles and folds across its plains and craters, caused by the cooling and contraction of the planet's core.

4 Shock waves

Impacts with large meteorites actually send shock waves through the core of the planet and around its perimeter.

1 Meteorite impact

Mercury has been continually hit with comets and meteorites. The largest of these impacts have effects across the planet.



5 Uplifted crust

The shock waves force the rocky mantle to buckle upwards through the crust, forming mountains.

3 Ejecta

Impacts force debris high into the air on Mercury. Falling debris settles around the crater, creating an ejecta blanket.

2 Crater

Some craters are relatively shallow and narrow, but impacts with meteorites leave large craters.

4,879 kilometres

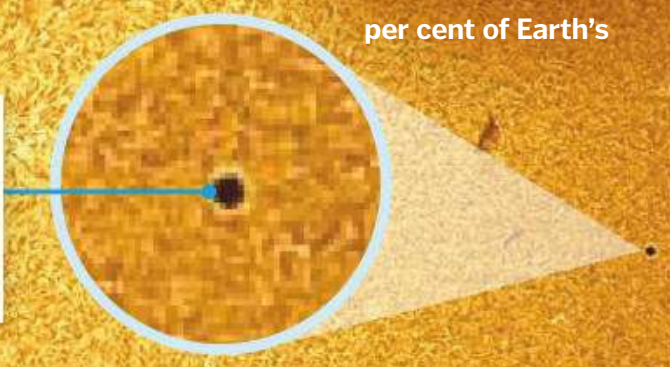
12,756 kilometres

Sizes

Mercury's diameter is two-fifths that of Earth, and its mass is roughly six per cent of Earth's

The transit of Mercury

Every seven, 13 and 33 years, Mercury can be seen as a black spot moving across the Sun.



The SOFIA telescope

This flying eye in the sky probes the secrets of the universe

The Stratospheric Observatory for Infrared Astronomy (SOFIA) consists of a Boeing 747SP wide-body aircraft modified to carry a telescope. Its infrared 2.5-metre reflecting telescope detects energy emitted by astronomical objects that are invisible to the human eye.

Pan American World Airways originally operated the Boeing 'jumbo jet' 747SP used in the project. The SP – or special performance – designation means that it has a shorter body and can travel further than the original 747 aircraft. NASA bought it in 1997.

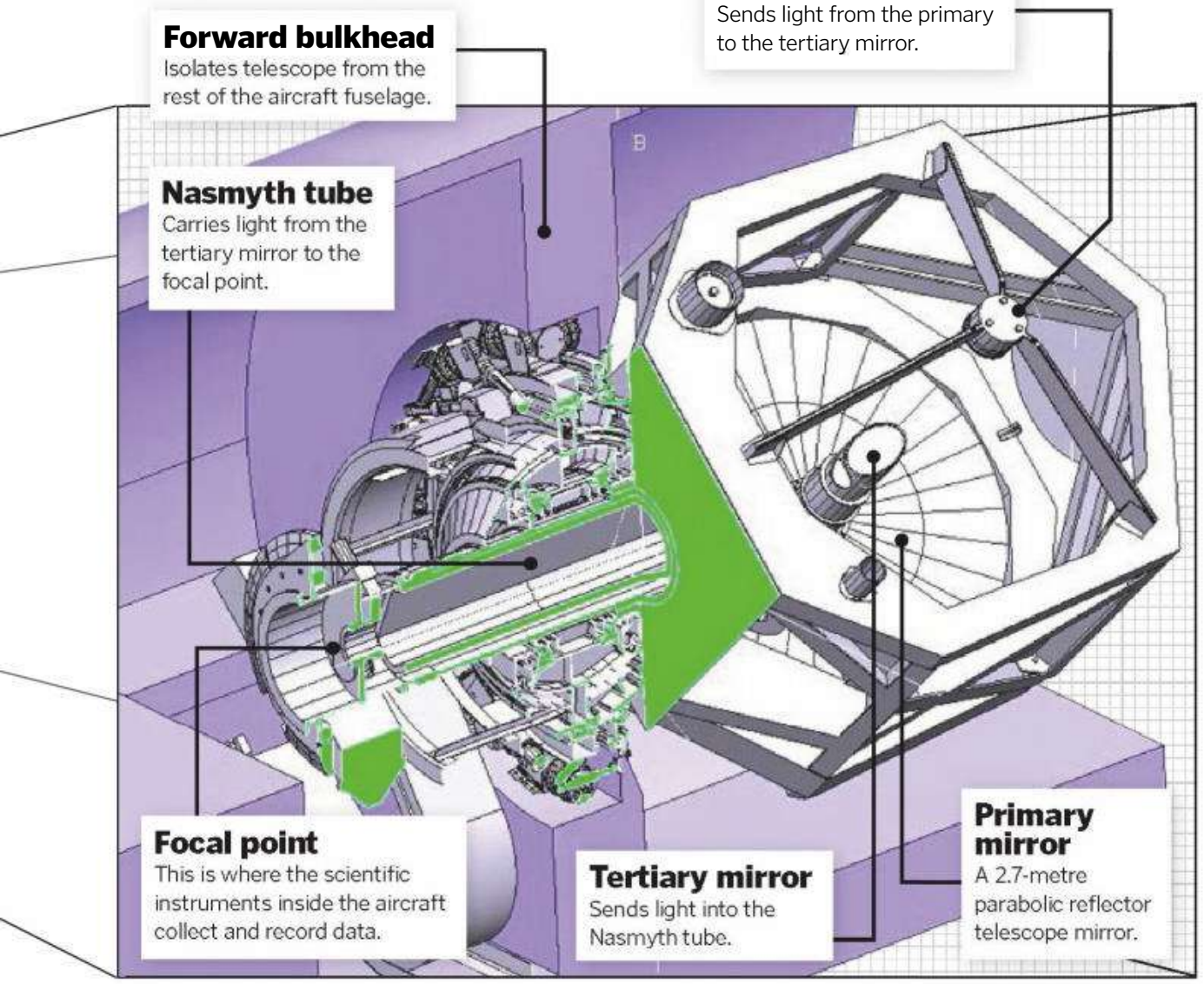
A section of another 747SP was used to mock-up the telescope design and structure before it was fitted to the SOFIA aircraft. The modified aircraft began test flying in 2007, and in December 2009 its telescope system began flight tests. It now operates from NASA's Armstrong Flight Research Center Building 703 in Palmdale, California, and saw first light in May 2010.

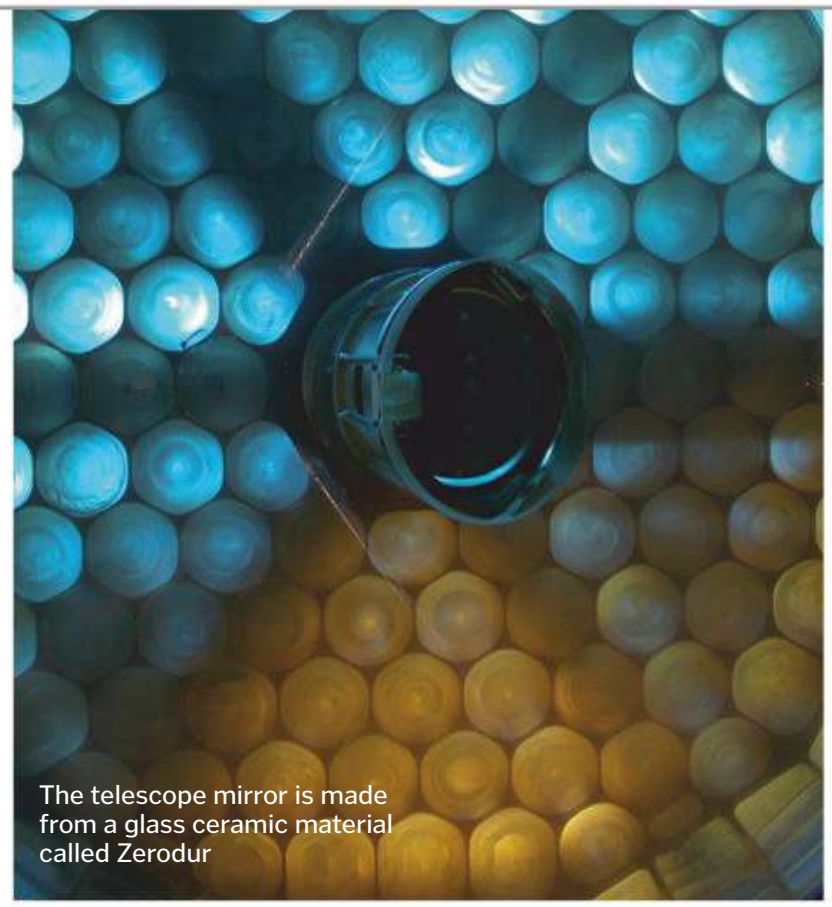
Travelling at a height of 12 kilometres at a speed of 800 kilometres per hour, the aircraft is subject to considerable shaking and turbulence. To counter this the telescope is mounted on a spherical pressurised oil bearing, and is stabilised by three gyroscopes that cope with sudden movements. A deflector fence on the rim of the telescope and the specially shaped side of the aircraft help deflect wind away from the telescope aperture. In addition, a distant star is tracked and used as a reference point to keep the telescope pointing in the same direction.

The main advantage of observing with SOFIA is that it can fly in the stratosphere, which is typically nine to 12 kilometres above Earth. At this altitude it can detect cosmic infrared radiation that is normally absorbed by water vapour in the lower atmosphere. This makes it far more effective than ground-based infrared observatories and puts it in the same league as satellite-based telescopes.

The SOFIA observatory (front) with its predecessor the now-retired Kuiper Airborne Observatory (back) at NASA's Ames Research Center

SOFIA's telescope


Forward bulkhead
Isolates telescope from the rest of the aircraft fuselage.
Secondary mirror
Sends light from the primary to the tertiary mirror.
Nasmyth tube
Carries light from the tertiary mirror to the focal point.
Focal point
This is where the scientific instruments inside the aircraft collect and record data.
Tertiary mirror
Sends light into the Nasmyth tube.
Primary mirror
A 2.7-metre parabolic reflector telescope mirror.


The telescope mirror is made from a glass ceramic material called Zerodur

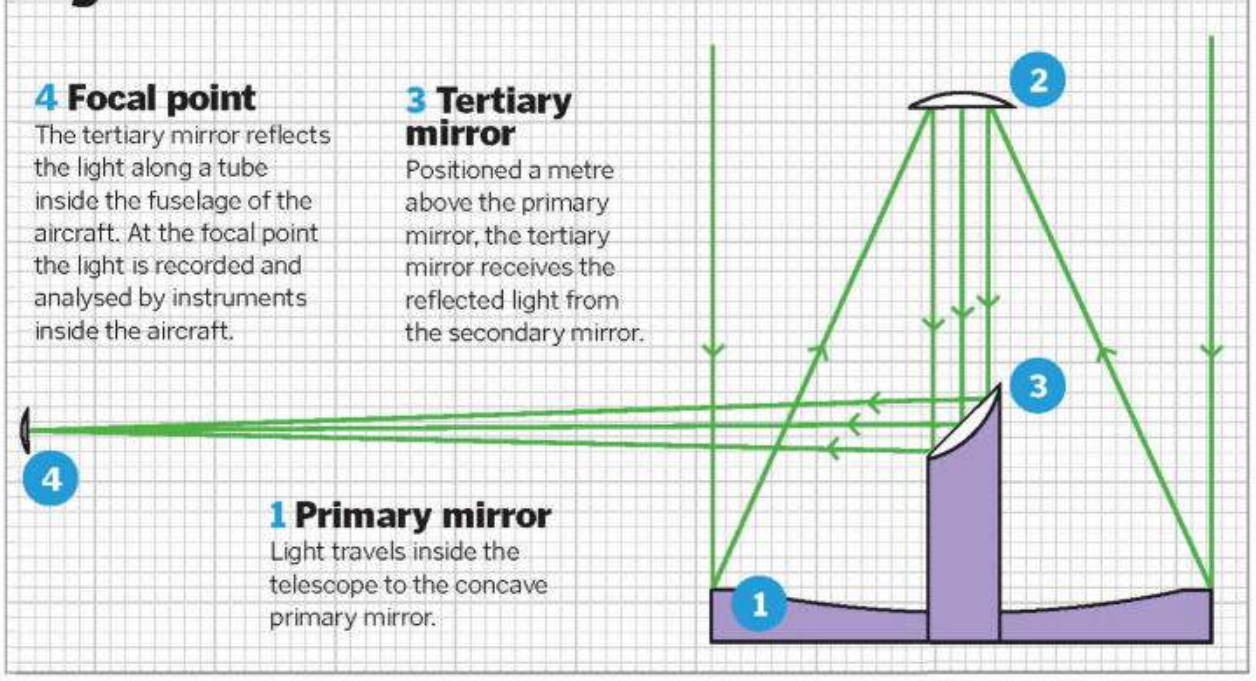
SOFIA versus Hubble

The Hubble Space Telescope and the SOFIA telescope have several similarities, along with some stark differences. They are both long-term projects that are intended to have a life of at least 15 to 20 years – though Hubble has now passed its 30th anniversary of observing the universe.

In the case of the Hubble Space Telescope, it operates around 550 kilometres above Earth and is equipped to record optical and ultraviolet light. SOFIA, flying at an altitude of 12 kilometres, concentrates on detecting infrared light and is able to study planetary details and the formation of galaxies.

The beauty of SOFIA is that new instruments and set-ups can be easily fitted and tested, whereas Hubble needed a Space Shuttle mission specifically for repairs. Notably, SOFIA costs a tenth of Hubble.

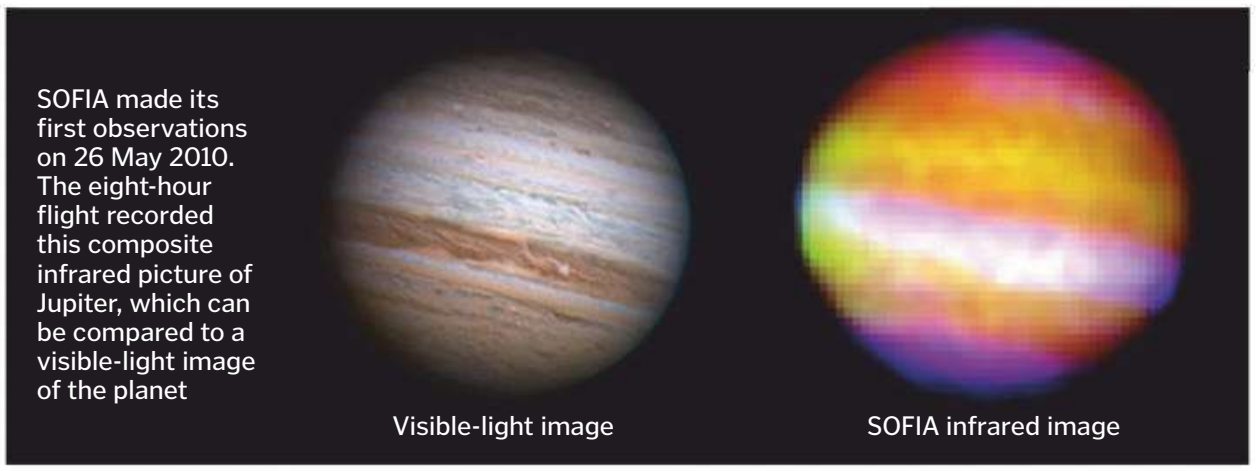
SOFIA's optical system


2 Secondary mirror
The light reflected from the primary mirror is reflected up to the 0.4-metre secondary mirror.
4 Focal point
The tertiary mirror reflects the light along a tube inside the fuselage of the aircraft. At the focal point the light is recorded and analysed by instruments inside the aircraft.
3 Tertiary mirror
Positioned a metre above the primary mirror, the tertiary mirror receives the reflected light from the secondary mirror.
1 Primary mirror
Light travels inside the telescope to the concave primary mirror.
1
2
3
4

Visible-light image

Visible-light image detail

Besides Jupiter, SOFIA has also recorded infrared images of Messier 82. It shows the formation of stars normally hidden by visible wavelength images


SOFIA made its first observations on 26 May 2010. The eight-hour flight recorded this composite infrared picture of Jupiter, which can be compared to a visible-light image of the planet

Visible-light image

SOFIA infrared image

SOFIA infrared image

All images © NASA

MEGAYACHTS

A statement of power and prestige, superyachts boast some of the most advanced designs, technology and equipment in the world

YachtPlus 40 'Signature Series' Ocean Pearl

Designed by notable architect Norman Foster, the YachtPlus 40 'Signature Series' brings a contemporary style to nautical tradition

The 41-metre-long Ocean Pearl, one of YachtPlus' 'Signature Series' of superyachts, was the culmination of a design process that took over 15 months by a team of seven architects under the stewardship of Lord Norman Foster and the technical prowess of the Rodriquez shipyard in Italy. The result is an incredibly spacious ocean-going vessel, bigger and more luxurious than many other yachts in its category.

The Ocean Pearl is powered by twin 1,044kW Caterpillar C32 diesel engines which allow a top speed of 17.5 knots and a regular cruising speed of 16 knots, at the latter speed allowing a maximum range of 2,400 nautical miles. Fuel consumption lies at 127 litres per hour at 12 knots. The hull and superstructure are both built from pure aluminium, allowing unparalleled lightness, and the Ocean Pearl's displacement lies at 205 tonnes at full-load.

On board there's a host of luxury amenities and facilities – a bar, saloon, pool, full-beam owner cabin, two VIP cabins and two guest cabins – as well as a complex and fully integrated computation and lighting system. Powering the Pearl are twin 86kW generators, which keep the lighting, navigation and communication systems going, as well as its twin CQR anchors, twin 3,100-litre-per-day water makers and a submergible beach deck.

Lürssen Arkley

Built by master craftsmen at Lürssen, the Arkley superyacht brings a level of luxury to its owners that only the richest will experience in their lifetime

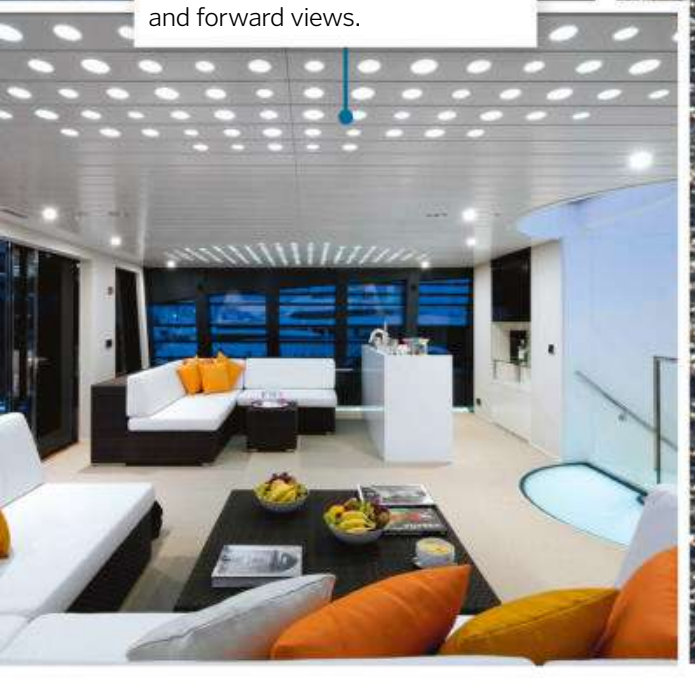
Most luxurious
Here's what 60 metres of luxury looks like.

The yacht's next-generation bridge

Captain's control room
The control station for the entire yacht. Communication, direction and navigation systems are used here.

© YatchP us

Panoramic saloon
An open area of the yacht, the panoramic saloon offers aft, side and forward views.



The statistics

Ocean Pearl

Designer: Foster + Partners
Builder: Rodriquez Cantieri Navali
Cost: $20 million
Length: 41 metres
Propulsion: Two 1,044kW Caterpillar C32 diesels
Displacement: 205 tonnes (full-load)
Max speed: 17.5 knots
Range: 2,400 nautical miles

The statistics

Lürssen Arkley

Designer: Exterior: Espen Oeino Interior: Mark Berryman
Builder: Lürssen
Cost: Undisclosed
Length: 60 metres
Propulsion: Two 1,455kW Caterpillar 3512B diesels
Displacement: 1,071 tonnes
Max speed: 15.5 knots
Range: 7,000 nautical miles

Lengthier and more voluminous than the smaller 41-metre Ocean Pearl, the Arkley by Lürssen is characteristic of this generation of superyachts.

In terms of raw statistics the Arkley doesn't disappoint. Sporting a 60-metre length and a displacement of 1,071 tonnes, the yacht is powered by twin Caterpillar 3512B 1,455kW diesel engines that produce a combined 3,958 horsepower. This colossal power allows for a top speed of 15.5 knots and a maximum range of 7,000 nautical miles. It's not short of juice either, with the yacht packing three Caterpillar C18 generators that provide the ship's electronics with a total 903kW of energy. Fuel capacity lies at 160,000 litres, while fresh water capacity clocks in at 30,000 litres, both of which mean that refuelling is a rarity.

State-of-the-art technology comes in the form of its steel hull and aluminium superstructure, twin Reintjes WAF 742 gearboxes, twin Rolls-Royce Tenfjord SR562 FCP steering gears, Jastram 40 F BU 3038 – 200kW bow thrusters and Quantum QC1800 stabilisers. On board the integration of advanced technology continues with all guest suites' windows dressed with low-noise electronic blinds, wall-integrated LCD televisions, a complex in-built speaker and audio system, a single-ducted air-conditioning system and even a fully functioning cinema.

Hot tub up top
The top deck features a jacuzzi and sun deck.

118 WallyPower

This sleek and futuristic-looking vessel was used in the Hollywood movie *The Island*, taking yacht power and performance to a whole new level

Concealing its every function in order to maintain the high engineering content of the yacht – as well as preserving its futuristic and sleek lines – the 118 WallyPower has arguably the most advanced aesthetics of any yacht in operation today. While relatively small at 36 metres, it boasts a massive power output, allowing it to cruise at speeds of 60 knots, a speed that utterly obliterates other larger and statelier yachts. For this reason alone it must be classified as not just a 'motor yacht', but a 'fast motor yacht'.

Power is central to the 118 WallyPower, and it supplies this colossal amount of thrust courtesy of three DDC TF50 gas turbine engines, each producing a maximum power of 5,600 horsepower for a grand total of 16,800. This figure is astonishing in its own right, allowing awesome performance and range – at 60 knots the 118 WallyPower has a maximum range of 380 nautical miles, or 437 miles on land. That's the distance from Monaco to Paris. This is especially impressive when you consider the number of luxury facilities and the advanced technology it is carrying.

Amenities include accommodation for six guests, two in the owner's stateroom – fitted with a king-size bed, his and hers en-suite and large wall-mounted LCD television – and four in twin guest cabins, an extensive saloon with a sculpted table and seats for 12, three crew cabins for the 118's six crew members, an advanced galley fitted with designer appliances, a hydraulically operated aft gangway and swimming ladder, a Prestige 4.5-metre, 40-horsepower tender with accompanying garage, a teak deck finish and spacious social cockpit for group observation on the move.

In terms of advanced technology the 118 WallyPower delivers a carbon-fibre and laminated composite glass superstructure, Technav sound and vibration analysis, multiple interceptors, MedTec hydraulics, Max Power 450R bow thrusters, Frigomar air conditioning, C. Plath Navipilot V HSC autopilot, Furuno GP-80 GPS system, Pathfinder Radome 48 radar, a C. Plath gyrocompass, a Furuno FM-2721 VHF and B&G depth-sounder and wind instruments.

Unsurprisingly this level of next-gen technology has led to the 118 WallyPower being noticed on the world stage, and since its launch it has been featured in the film *The Island* and BBC motoring show *Top Gear*, in the latter of which the 118 was raced against the Pagani Zonda hypercar.

Inside the control room

Not the comfort you'd get on the ferry to Calais

The statistics

118 WallyPower

Designer: Wally with Luca Bassani and Lazzarini Picker
Builder: Wally / Intermarine Italy
Cost: $33 million
Length: 36 metres
Propulsion: Three DDC TF50 gas turbines
Displacement: 95 tonnes (half-load)
Max speed: 60 knots
Range: 1,500 nautical miles

© WallyPower

Galley/crew mess

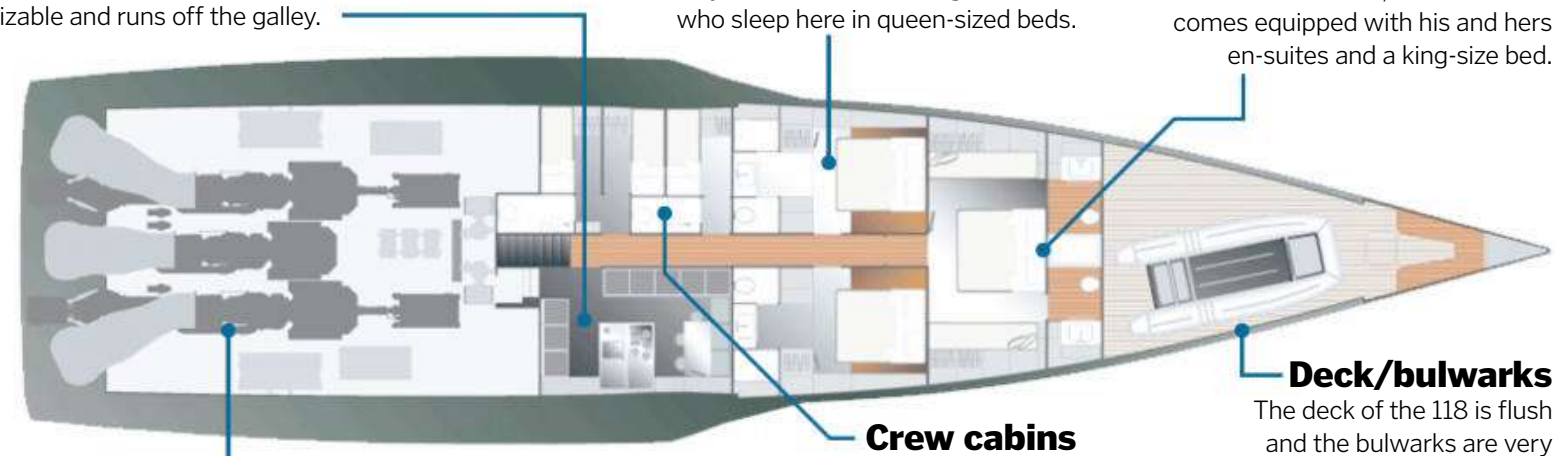
The galley is state of the art and is equipped with designer equipment. The crew's mess is sizable and runs off the galley.

Guest cabins

Due to its smaller size the 118 can only accommodate four guests, who sleep here in queen-sized beds.

Owner's stateroom

The largest and most spectacular bedroom on the 118, the stateroom comes equipped with his and hers en-suites and a king-size bed.



Deck/bulwarks

The deck of the 118 is flush and the bulwarks are very high at 64 centimetres, ensuring good protection for the side decks.

Crew cabins

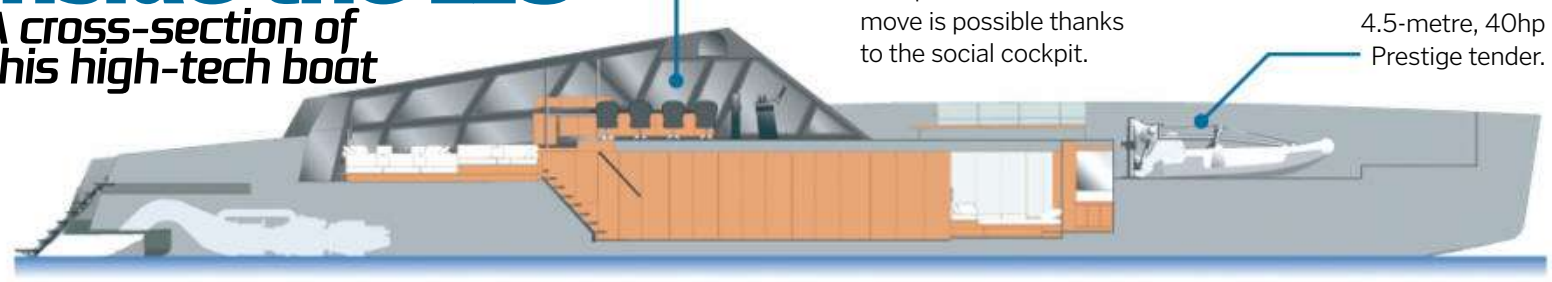
The 118 has a crew of six, with three two-bed cabins positioned off the galley.

Engine room

The vast engine room is aft, perfectly sound and vibration isolated. It houses the 118's three DDC TF50 gas turbines.

Inside the 118

A cross-section of this high-tech boat



Social cockpit

Group observation on the move is possible thanks to the social cockpit.

Tender garage

The home for the 118's 4.5-metre, 40hp Prestige tender.

The ultimate yacht

We combined three of the most awesome superyachts of recent years to create one ultimate yacht

Each of the three aforementioned superyachts are incredible in their own way. The Ocean Pearl brings ultimate design theory to the table, while the Lürssen Arkley is one of the top in its class in terms of luxury facilities, allowing many guests and its owners to travel vast distances in five-star surroundings and service. The 118 WallyPower, however, destroys both in terms of power, allowing for a blistering top speed of 60 knots and dynamic speedboat levels of performance.

It's therefore quite a tough decision when picking that perfect present to sail away on into retirement. Here at How It Works, though, we don't like making compromises and demand the best of everything, be it sleek lines, marble floors or Jeremy Clarkson-levels of thrust, so we decided to combine the three to create the ultimate superyacht. By borrowing the best properties and parts of each yacht, we could create a yacht so awesome and so unsurpassable that no other superyacht would ever need to be built again.

The statistics

HIW superyacht

Designer: How It Works
Builder: Future Publishing
Cost (estimated): $67 million
Length: 62 metres
Propulsion: Three DDC TF50 gas turbines
Max speed: 30 knots
Range: 3,300 nautical miles

STERN

Power it up

By using the 118 WallyPower's triple DDC TF50 gas turbine engines, our superyacht, despite its larger size, would still have a high top speed of 30 knots, allowing you to leave other yachts its size in the dust.

MIDSECTION

All the luxuries

The facilities on the Arkley are staggering, so by taking its midsection we get a jacuzzi, king-sized beds, massive HD TVs, a well-stocked bar and a pantry so large you could get lost in it. In addition, the vast array of rooms would allow for many guests to be accommodated.

BOW

Pearl of a front

With its open and sleek design – with lines to make Enzo Ferrari stand back in appreciation – the bow has to come from the Ocean Pearl. 30 per cent more open space would also come in handy on sunny days, and the superstructure's super-hard frame would keep things light but crash-resistant.

Future-proof

In addition to its power advantages, the futuristic styling of the stern would future-proof the yacht, allowing you to not only outrun invading aliens, but do so in a contemporary style.

Staff quarters

It's no use having such a large yacht if you have no one to crew it, so by taking the midsection of the Arkley you would also get plenty of room for the extensive staff quota. After all, it's pointless having the largest stock of martini on board if no one is there to shake it.

Tender up top

Due to the lack of room in the rear of our yacht, we would transfer the yacht's main tender and jet skis to the bow, allowing for high-speed fun off the main yacht and providing a method of ferrying people to and from it.

How petrol pumps work

Peek inside the fuel-pumping petrol dispenser

Next time you're lost in boredom at the petrol pump, think about this. Several metres below you are three massive storage tanks. Two of them contain regular unleaded petrol – one with the highest octane grade of fuel, the other with the lowest – and the third holds diesel.

When you select your fuel grade and pull the trigger, suction pumps inside the petrol dispenser draw up fuel from both the high- and low-octane tanks and blend them to the precise octane level. A spinning 'fuel-O-meter' inside the pump records how much petrol flows past, keeping track of your purchase. Since petrol expands and contracts with hot and cold weather, a temperature probe compensates for fluctuating volume, ensuring you get what you pay for.

In the old days, caustic petrol vapours seeped out of the tank during a fill-up. Modern petrol stations are equipped with vacuum pumps that siphon out the offending fumes and store them safely below ground in the fuel tanks.

If you were to look inside the fuel nozzle, you'd see that the dispenser line is held open by air pressure from within the tank. When the fuel level reaches the tip of the nozzle, the air pressure is choked off and the dispenser switches off automatically.

8 User interface
Modern petrol pumps are equipped with interactive computer screens to walk the customer through the fuel selection, pumping and payment processes.

4 Flow meter
As the fuel is dispensed, the flow of petrol turns a series of rotors that measure the volume of liquid being pumped, which is displayed in real-time.

3 Suction pump
The pump sucks air out of the dispenser hose, creating less air pressure above the petrol and causing the fuel to rise upward.

2 Dispenser hose
Think of the dispenser hose as a long, twisty straw inserted into the storage tank on one end and connected to a motorised pump on the other.

7 Vacuum pump
This pump powers the vapour-recovery systems now standard at modern petrol stations. Instead of allowing noxious fumes to escape, they are siphoned back into the fuel storage tank.

1 Underground tanks
There are separate double-skinned storage tanks for high- and low-octane petrol and diesel, each one holding between 25,000 and 50,000 litres of fuel.

Breather pipes
Dispenser
To other storage tanks
Earth (ground) cable
Inspection hatch
Fuel pump to dispenser
Vapour pumped to tank
Vapour
Dispenser pump hose
Storage tank filling hose
Petrol
Double-skinned tank
Gauge well
To other storage tanks

Fuel nozzle detail

Vapour
Petrol

5 Fuel nozzle
When you pull the nozzle trigger, it dispenses petrol and sucks out vapours from your fuel tank.

Filling cut-off valve
Nozzle trigger
Vapour recovery

6 Overfill detector
A vacuum pump sucks air from a narrow tube next to the fuel nozzle. If the petrol level rises up to the tube, the pump senses the change in pressure and triggers a cut-off valve.

Vapour
Petrol

What's in your tank?

In its purest form, petrol is nothing but a string of carbon and hydrogen atoms. It is distilled and separated from crude oil (petroleum) through the refining process. Unlike other oil-based fuels like butane or propane, petrol has a relatively high boiling point, making it more stable.

But the gas at the pump isn't pure petrol. It contains a blend of additives and stabilisers that help the fuel burn cleaner, store longer and make your engine run efficiently. Additives called oxygenates increase the oxygen content of petrol, enhancing its octane level and helping it burn cleaner. Antioxidants are added to decrease the formation of sediments in tanks. Finally, detergents and anti-corrosive agents are added to keep engines running clean.

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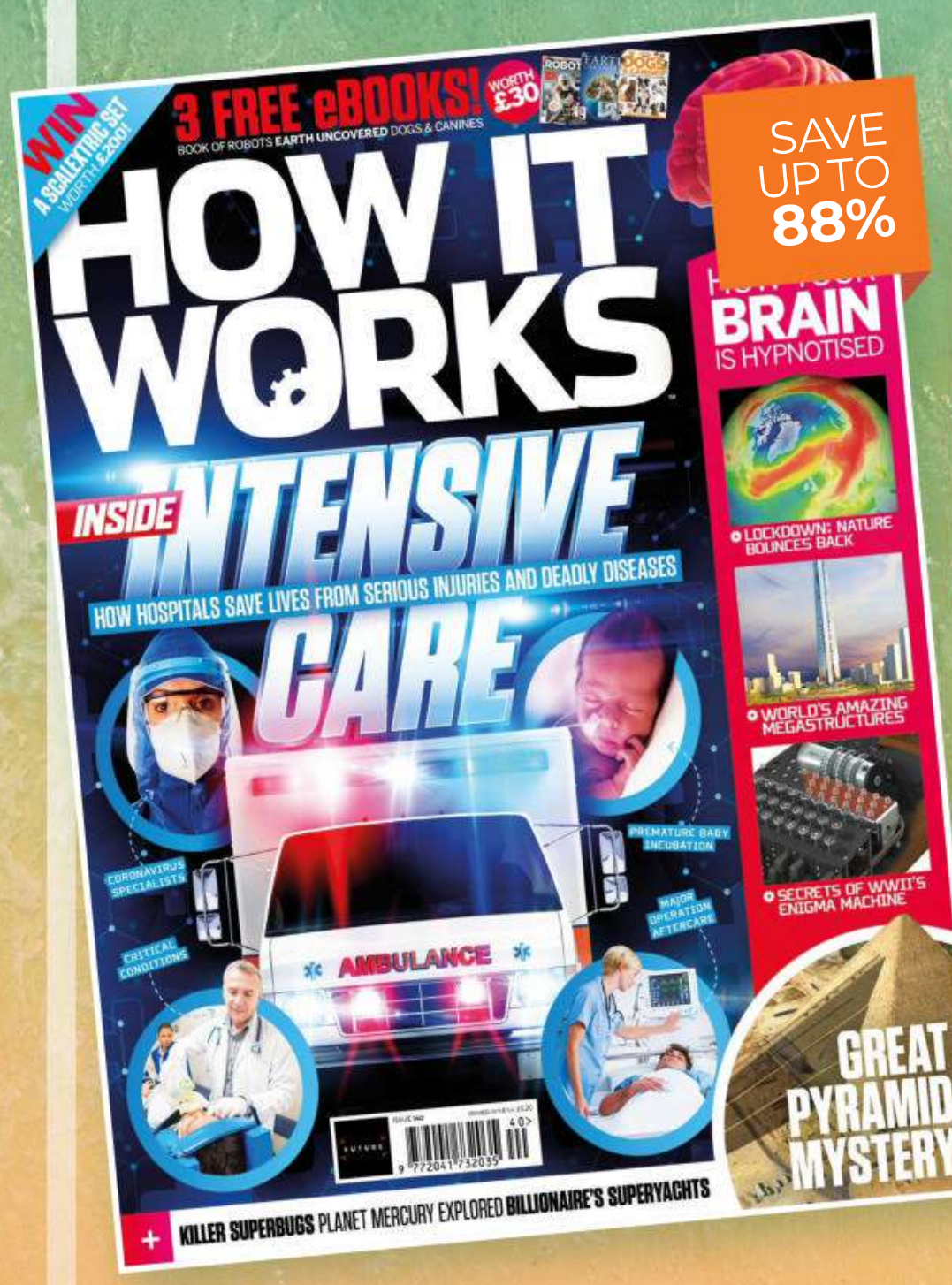
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BRAIN DUMP

Because enquiring minds need to know...

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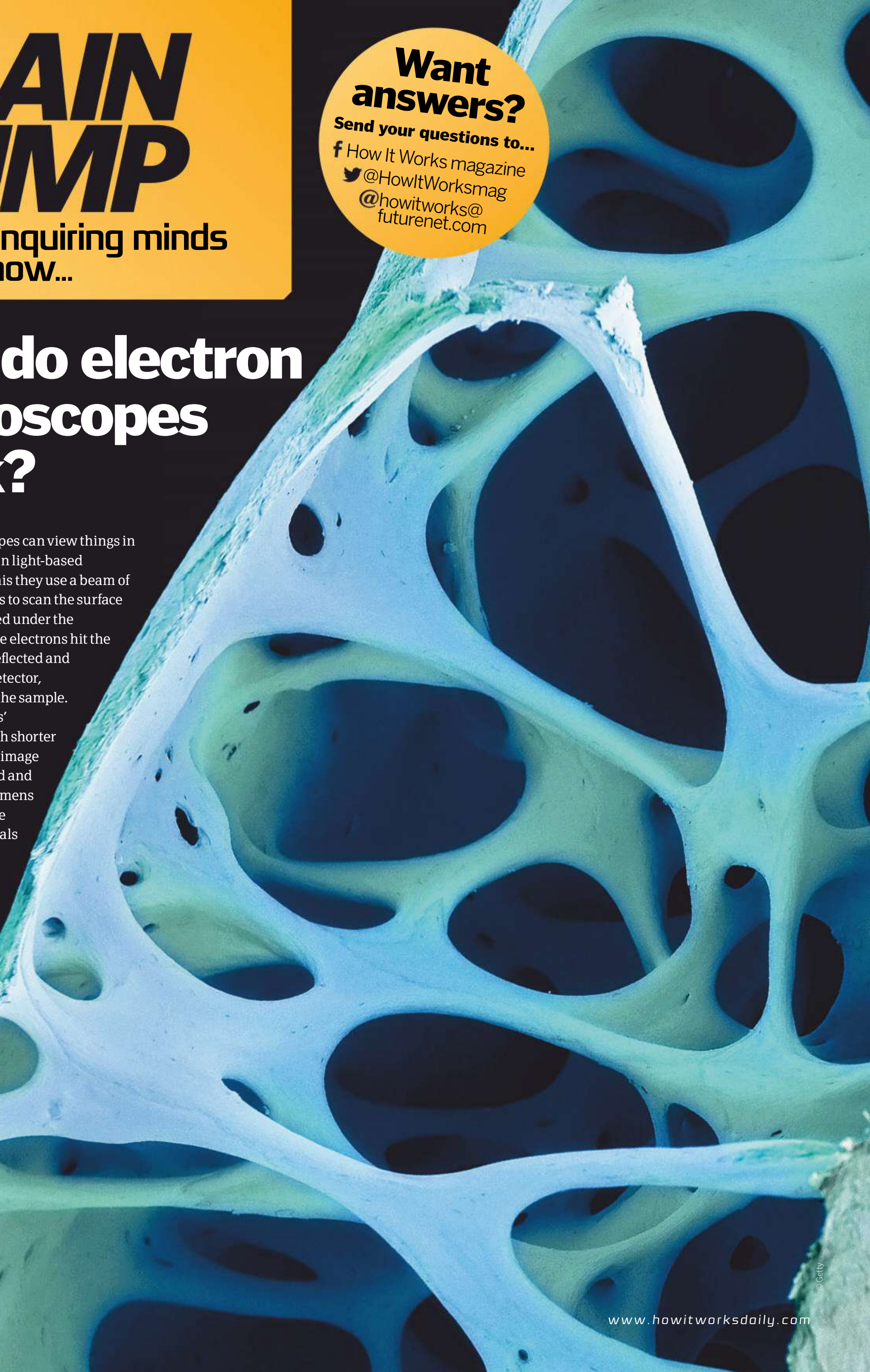
How do electron microscopes work?

Jacob Crowley

Electron microscopes can view things in much more detail than light-based microscopes. To do this they use a beam of high-energy electrons to scan the surface of the specimen placed under the microscope. When the electrons hit the specimen, they are reflected and directed towards a detector, creating an image of the sample. Because the electrons' wavelengths are much shorter than that of light, the image is much more detailed and can show small specimens such as bacteria or the minute details of metals and crystals. **AH**

This close-up image of a bird's bone was taken with an electron microscope with colour added



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The bright colours associated with poison are unnatural to our eyes

Why do we associate purple and green with poison?

Kevin Shu

In nature, a lot of deadly plants and animals display bright colours as a warning to keep away. While deadly poisons are found in nature, these can also be created synthetically, and bright and unnatural colours such as green and purple reflect the dangerous, unnatural properties of these substances. Green in particular is also linked to toxic and radioactive substances, especially after the discovery of radium by Marie and Pierre Curie in 1898, which was found to emit a green 'glow'. This association has passed into popular culture, with films and video games adopting these colours to represent poisons and the artificial. **NR**

© Getty

Why do we turn in our sleep?

Stephen Conn

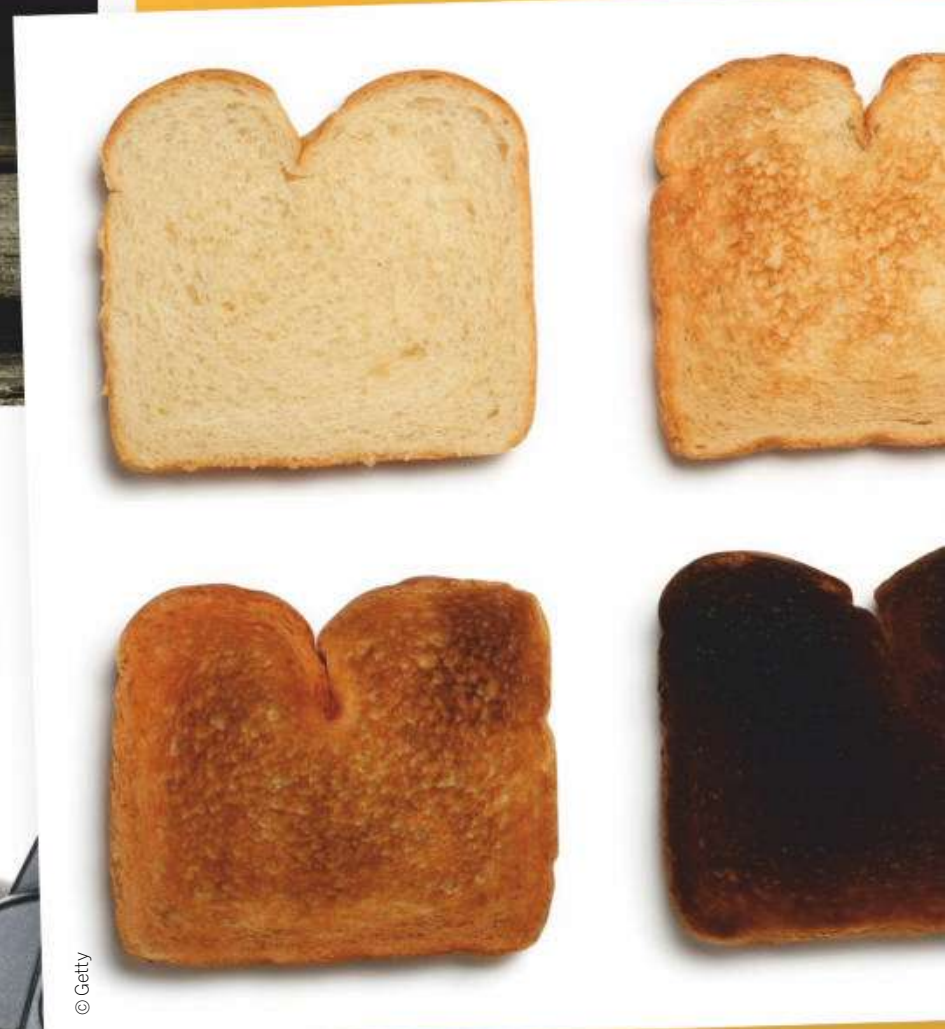
While some believe unconsciously shifting our sleeping position is simply a matter of getting more comfortable, others think it is a protective mechanism to ensure we aren't lying on one part of our body for too long, which can reduce blood flow and build up pressure. Tossing and turning in the night can also be an involuntary response to stress induced by bad dreams. **NR**

Can you put a PS2 emulator on a Raspberry Pi and connect a PS2 controller to it?

Nicola Robinson

You certainly can, although you will need a Raspberry Pi 2 or later to run it properly, extra hardware in the form of a Playstation 2 port to connect to the Raspberry Pi and a compatible emulator. **BB**

A Playstation 3 controller can also be connected to a Raspberry Pi computer



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How much carbon do you like on your toast?

How come when bread gets burned, it turns black?

Ayman Rehab

When organic material – in this case a slice of bread in the toaster – gets heated up, a reaction takes place. The carbon in the bread is combusted, leaving behind burnt carbon as a waste product. This is what gives burnt toast its blackness. **NR**

BRAIN DUMP

200 million years ago, Gondwana incorporated most of the landmasses that make up today's continents of the Southern Hemisphere

Were New Zealand and Australia once connected?

Simon Xu

New Zealand and Australia were joined together, along with Antarctica and Africa, in a huge supercontinent called Gondwana. Around 85 million years ago the two countries separated by continental drift when New Zealand broke away. **AH**

© Getty

Vampire bats have to continually feed on blood, as missing just two meals could cause them to starve

© Alamy

Why are vampire bats the only bats to seek blood?

Caroline Ward

There are several species of vampire bat in the world, and they've been found to be the only known mammals to solely survive by drinking the blood of other animals. The reason vampire bats can survive this way is that – unlike their fruit- and insect-eating cousins – their gut microbes work differently to digest blood, along with a built-in resistance to bloodborne viruses. Their DNA has also hardwired their kidney function to tolerate the high-protein intake that comes with a blood-only diet. **SD**

A California gray whale harbouring clusters of barnacles on its head

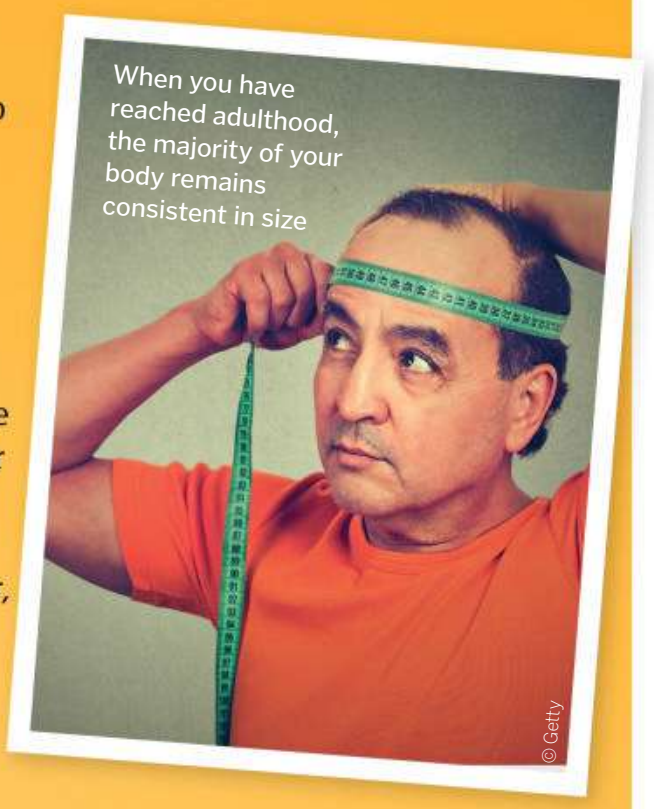
© Getty

Which body part is last to stop growing or developing?

James Dark

Many consider the end of puberty to be the point of full development, but in actuality the body continues to change throughout life. In fact, some body parts never stop growing, and are therefore the last to stop developing. Internal organs such as the brain are forever developing with the intake of new information and fluctuating conditions inside the body.

Aside from the likes of hair and nails – which can continue growing for a short time after death – there are really only two external body parts that grow in size for the rest of your life. These are your ears and your nose. Both made of soft tissue and cartilage, some scientists believe the cartilage cells are able to multiply for longer, while others suspect the long-term pull of gravity to assist this growth. **AH**



© Getty

Why are whales not covered in seaweed?

Clément Roubertie

Much like plants on land, seaweed grows along the seafloor, far out of reach from passing whales overhead, and so rarely comes into contact to latch onto their skin. However, some species of whale do find themselves ferries for small colonies of barnacles, which attach to their skin as free-swimming larvae and develop into their hard shells as adults. **SD**

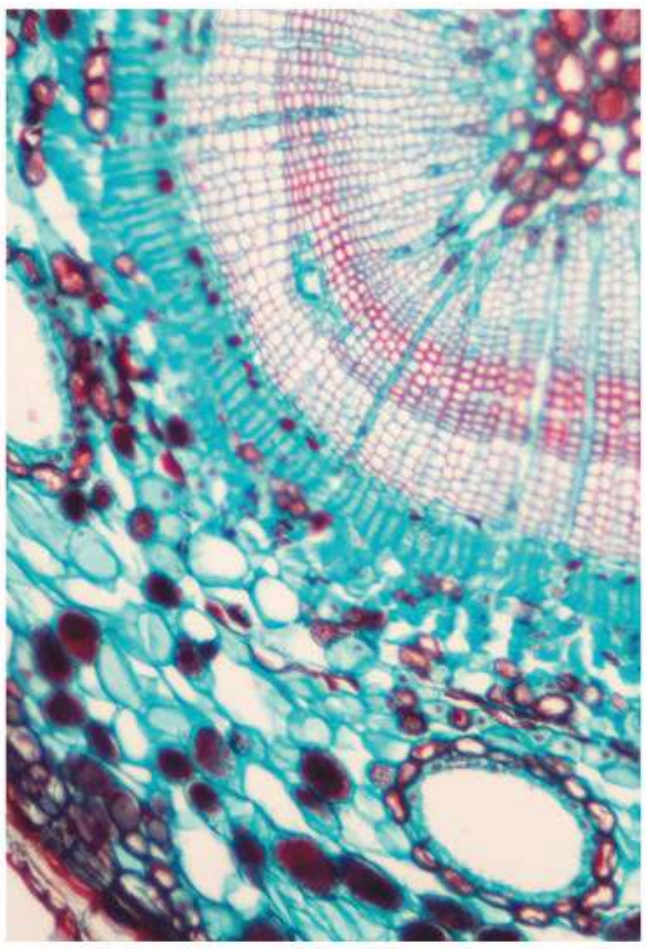
Why does grey hair grow at different rates?

Antonio Buggin

As we age, our hair follicles naturally decrease in their productivity of melanocytes, cells located in the skin's epidermis containing a pigment called melanin. As production decreases, the colour of our hair follows suit. This decolourisation occurs within the individual life cycle of each hair strand on our bodies. The reason these grey hairs may appear in different places and grow at different rates is based on where a single hair is in its life cycle. As one hair falls out, a new grey hair has a chance of replacing it. Each one of our hair follicles is at a different stage in the cycle, so all hair does not grow in unison. Factors such as stress and inherited genetic traits can also contribute to when and where the greys begin to sprout. **SD**

© Getty

Typically, grey hairs begin to appear over the age of 35



© Getty

Stem cells aren't exclusive to humans, or even animals: this is a microscopic view of a stem cell from a flowering plant

Can you tell me more about stem cells? How are they used? How are they extracted?

Thomas Nash

Stem cells have the incredible ability to change into any other cell type – skin, muscle, bone… even cells of complex organs like the liver or brain. There are two main types: embryonic or pluripotent stem cells, which are derived from embryos and can transform into any other cell type, and adult stem cells, which will only change into certain types of cell. Adult stem cells extracted from bone marrow can be treated in a lab to act like embryonic stem cells and are used to help people overcome certain diseases, such as replacing cells that have been killed by radiation therapy in the treatment of cancer. In the future we could use these stem cells to grow organs for transplants. **BB**

© Getty

The average colour of the universe is 'cosmic latte', a pale beige. Where does the pale colour come from?

Anouk Wood

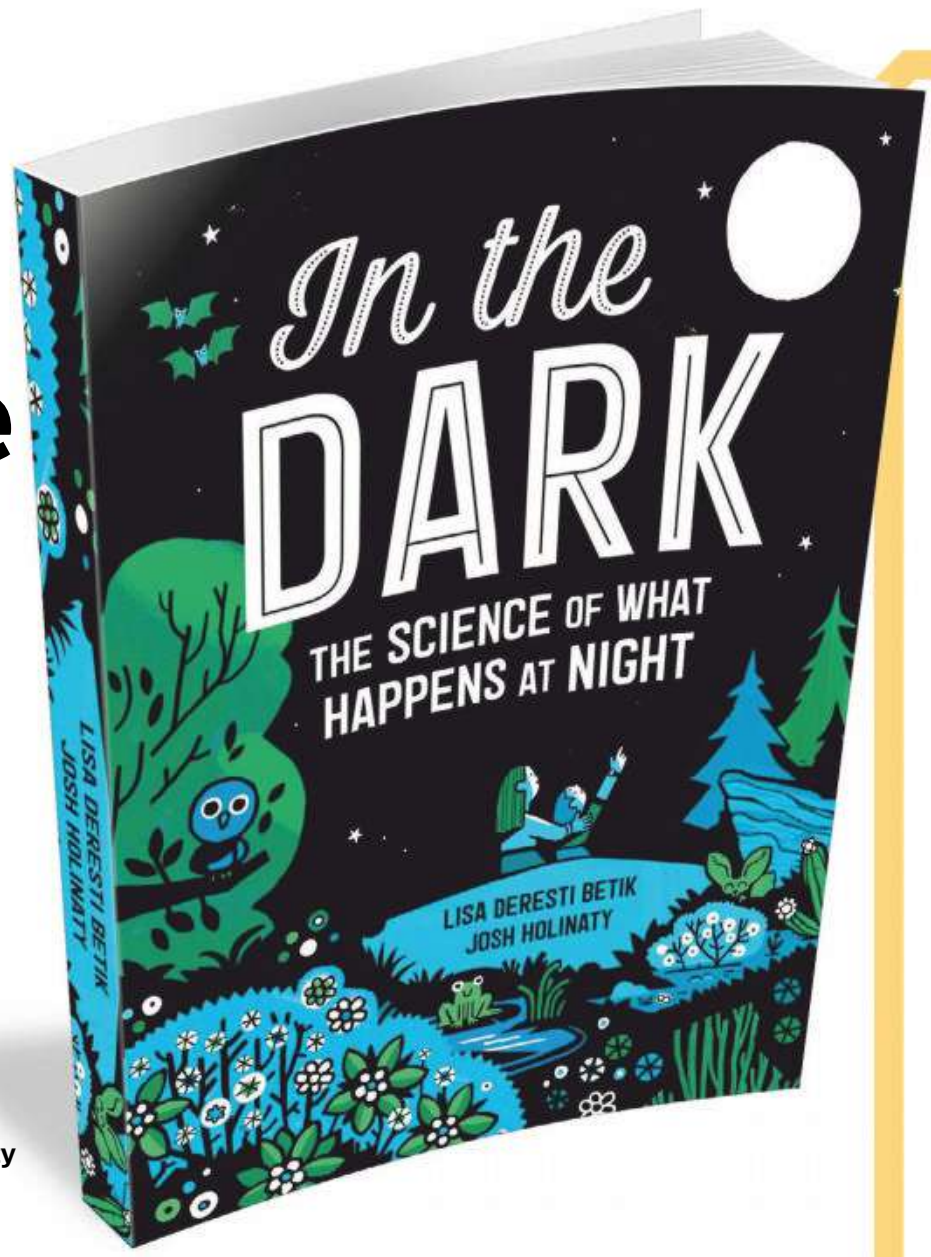
The average colour of the universe was calculated in 2002 by a study that looked at the light of over 200,000 stars. Despite much of the universe being characterised by dark, empty space, there are more than enough incredibly bright stars to make an average colour – as if you had mixed them all together – similar to a weak cup of coffee. **BB**

If you go to **color-hex.com** and enter the hex code #FFF8E7, you can see exactly what cosmic beige looks like

BOOK REVIEWS

The latest releases for curious minds

In the Dark: The Science of What Happens at Night



What things go 'bump' and why?

- Author: **Lisa Deresti Betik and Josh Holinaty**
- Publisher: **Kids Can Press**
- Price: **£15.99 / $18.99**
- Release: **1 September**

What better way to dispel the monsters hiding under the bed and those shades that haunt the corners of the bedroom than to give your child a better understanding of what goes on in the world when they go to sleep?

In the Dark is a light, entertaining and beautifully illustrated book for bedtime, if you like, but it's for any time really. The author has chosen an unusual catch-all topic that cherry-picks and expands upon interesting points in human biology, wildlife, the environment, astronomy and more. For example, you can expect to learn how owls echolocate their prey, the phases of the Moon, what happens in the 'deep dark sea' at night, why some people snore and even how plants calculate complicated mathematical sums when it's dark.

Lisa Deresti Betik's engaging and accessible writing is accompanied by Josh Holinaty's wonderful illustrations in the form of short comic strips, infographics, annotations and cutaways – a staple of **How It Works** magazine features – coloured in the faded pinks, navy blues and greys of twilight. Each topic is given no more than a page each, with short but pithy piece text that delivers curious facts on STEM-related topics that we'd wager many adults wouldn't be aware of. At 52 tightly written pages, it's shorter than we'd have liked, but only because we enjoyed it so much. There's also a short glossary of terms at the back that breaks down some of the harder science terms for younger readers and is worth a read in itself.

> "What better way to dispel the monsters hiding under the bed?"

For primary-aged children, there's ample value for money here: it will be a book they will return to time and time again. We only fear the unknown, and by arming your little ones with this knowledge, they will be more than capable of fending off nightmares by themselves when the lights go out.

★★★★★

What Do You Think You Are?

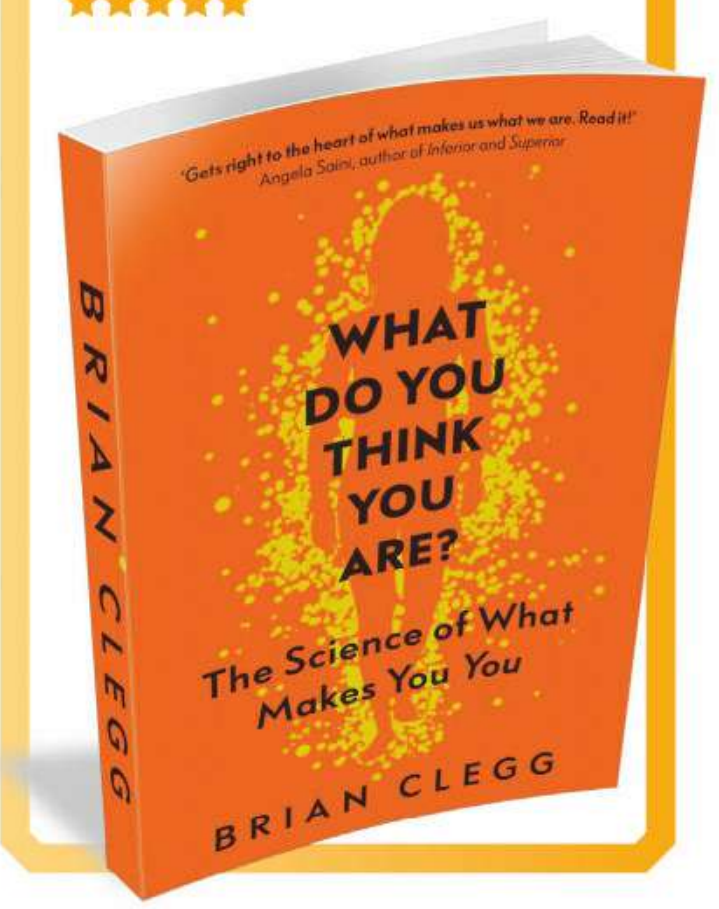
The science of what makes you *you*

- Author: **Brian Clegg**
- Publisher: **Icon Books Ltd**
- Price: **£18.58 / $22.95)**
- Release: **6 August**

It's a question we could spend our entire lives trying to answer on so many different levels. However, Brian Clegg's scientific approach tackles what it means to be a human on the most fundamental levels. Along the evolutionary route to becoming modern-day humans, Clegg explores the atoms that have travelled through space and time to build our bodies, our genetic make-up and the creation and advancements of our consciousness.

Clegg has left no stone unturned when it comes to answering the question on the cover, and in doing so has produced a book filled with not only excellent academic insight, but also a wonderfully told story of humankind and how each of us become who we are.

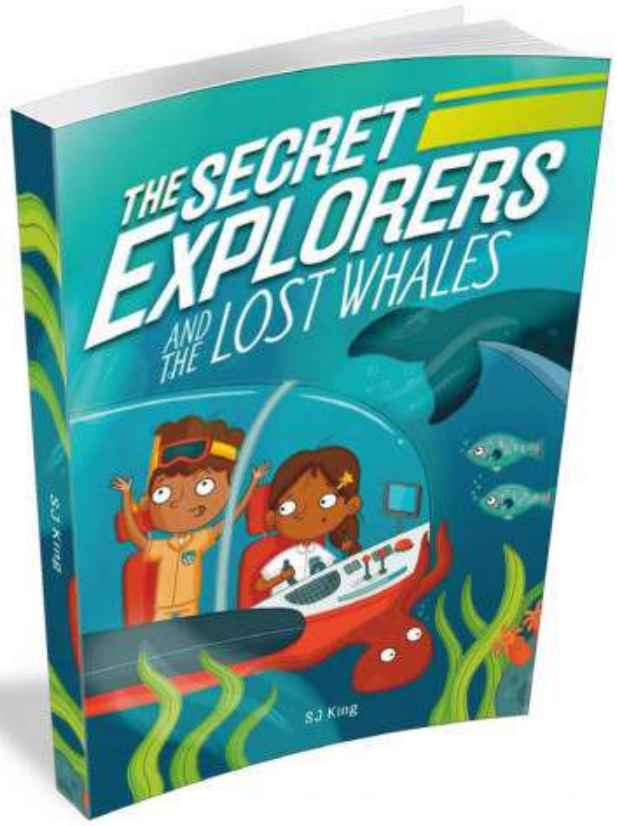
★★★★★


'Gets right to the heart of what makes us what we are. Read it!'
Angela Saini, author of Inferior and Superior
WHAT DO YOU THINK YOU ARE?
The Science of What Makes You You
BRIAN CLEGG
BRIAN CLEGG

The Secret Explorers and the Lost Whales

An adventure into unknown depths

- Author: **S.J. King**
- Publisher: **DK Children**
- Price: **£5.99 / $5.99**
- Release: **16 July**



Connor and Roshni have been selected for a secret mission to the depths of the ocean, and you're invited along too. As the adventure unfolds, marine enthusiast Connor and astronomy star Roshni use their knowledge of the world, along with their initiative, to help a pod of whales complete their migration.

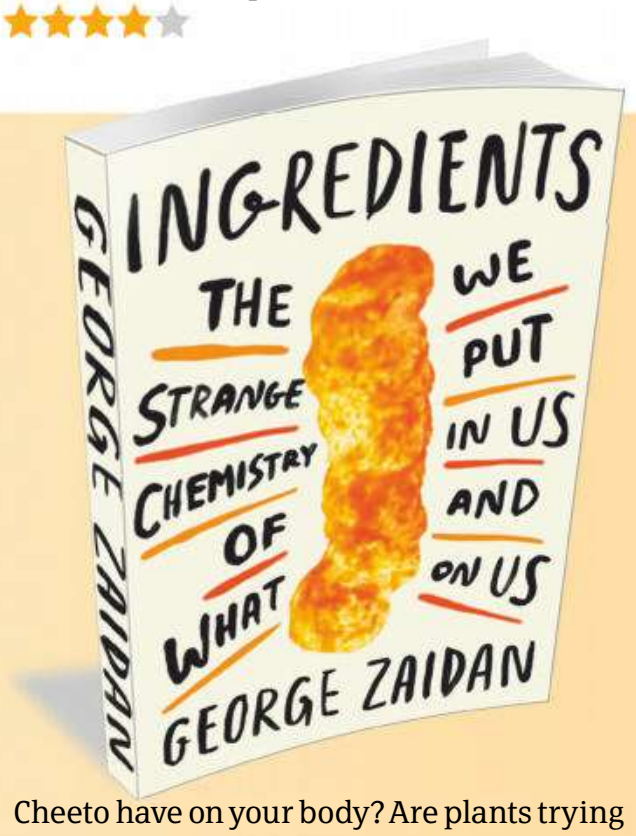
With fast-paced action throughout, Connor provides intriguing information about every encounter, educating both Roshni and the reader as the story unfolds. The story allows you to share Roshni's awe as you are mesmerised by camouflaged octopuses, singing whales and other weird and wonderful displays at the very bottom of the sea. Every obstacle faced provides a lesson to be learned about marine life, and not all are pretty. This book provides a child-friendly explanation of humanity's impact on the oceans, from plastic problems to fertiliser pollution. On every page the text is decorated with beautiful illustrations to bring the descriptions to life, and at the end there is a chance to recap on the facts within the fiction through an interactive quiz. The Secret Explorers really do help to make learning about the world a fun experience.

★★★★☆

Ingredients

Will that Cheeto kill you?

- Author: **George Zaidan**
- Publisher: **Dutton**
- Price: **£19.99 / $27.00**
- Release: **Out now**



How often do you view the ingredients on the back of your food products? Even if you check regularly it can be difficult to make sense of these long lists and complex codes. Every day we choose products to expose our bodies to, whether to consume in the form of food and drink or to cover our skin with in the form of beauty products.

This book delves deep into the chemistry of these products, from wine gums and coffee to sunscreen and the disturbing truths about swimming pools. By opening this book you are taking a journey, interpreting packets of data and exploring what this really means for you and your body. Not only are the simplified categories of 'good' and 'bad' foods explained, you are also provided with real-world facts that a list of numbers can't give you. How much damage can just one more processed Cheeto have on your body? Are plants trying to kill you?

As the author and illustrator, George Zaidan uses his knowledge as a chemist and clever humour to create witty analogies and amusing doodles. Each explanation is provided in a way that even those with no chemistry background can make sense of. *Ingredients* has its own components perfectly combined, and the final product merges serious statistics and original comedy in successful proportions. It may just change the way you look at some foods forever.

★★★★☆

Inventors

Incredible stories of the world's most ingenious inventions

- Author: **Robert Winston**
- Illustrator: **Jessamy Hawke**
- Publisher: **DK Children**
- Price: **£16.99 / $21.99**
- Release: **Out now**

The modern technological world we all now benefit from stands on the shoulders of the innovators and inventors throughout history that help to build it. It's something Robert Winston has successfully depicted in this informative and wonderfully illustrated book. From the work of recognisable figures such as Leonardo da Vinci to the less known, but equally important scientists that changed the course of history such as Stephanie Kwolek, *Inventors* explores the lives and scientific achievements of academic minds throughout the ages. Targeted at a younger audience, it's a book that the family can use to learn about the inventors they didn't know influenced the world around them.

★★★★★

"An informative and wonderfully illustrated book"

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Why did the 646-metre-tall Warsaw radio mast collapse?
- Lightning struck it
- It was blown up
- Strong wind damaged it
- It sunk into the ground

Q2 Which of these patients wouldn't you find in intensive care?
- Stroke
- Sepsis
- Traumatic brain injury
- Broken arm

Q3 What gives carrots their orange colour?
- Sunshine
- Beta-Carotene
- Iron-rich soil
- Microorganisms

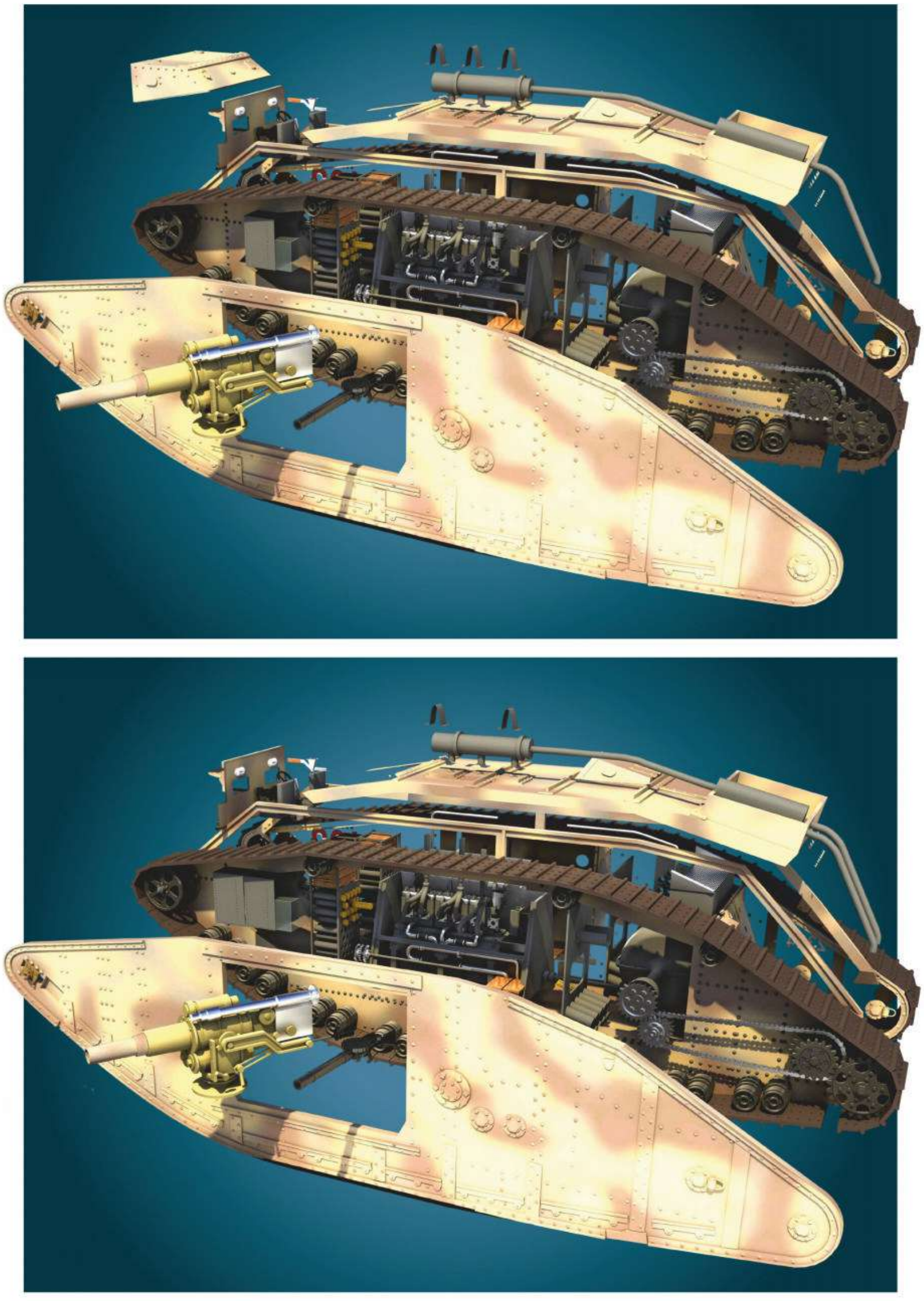
Q4 Why is the $4.8 billion yacht 'History Supreme' so expensive?
- Made with ten tonnes of gold and platinum
- It's nuclear-powered
- Leonardo da Vinci made it 500 years ago
- Because it doesn't exist

Q5 Where on your body can the bug MRSA live?
- On your brain
- On your skin
- In your blood
- In your stomach

Q6 Which planet is closest to the Sun?
- Neptune
- Venus
- Earth
- Mercury

Spot the difference

See if you can find all six changes between the images below



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	9		1		7	3	4	
		4	5		6	1	9	
5		3			9		6	7
4		5					2	
	6		8	4		5		3
		2	6	9	5	4		1
				7	1	8		2
1	5				8			4
8		7						9

DIFFICULT

					9			1
					7		2	
5	4							
7	3			6	2		4	
		9			8			
				3		5	7	
9		1						8
	5				6			3
6			7	4			9	

What is it?

Hint: Scientists painted this deadly work of modern art...

A .....

P	A	I	L	N	W	O	D	K	C	O	L	X	I	S
C	L	D	E	G	Y	H	G	A	F	J	P	O	N	T
O	K	A	D	E	E	B	O	N	T	I	M	R	S	A
P	I	V	N	J	H	R	S	A	X	I	A	Y	G	E
E	I	L	K	E	D	A	W	F	N	E	L	T	B	H
S	N	T	H	G	T	J	N	E	C	A	Y	P	O	Y
I	T	A	R	Y	S	Q	U	Z	I	S	L	N	E	P
B	E	C	L	P	O	Y	A	C	H	T	A	F	M	N
R	N	C	H	T	A	B	E	I	O	V	D	K	L	O
E	S	K	Y	S	C	R	A	P	E	R	O	R	S	T
B	I	D	O	W	T	S	O	R	P	K	C	A	E	I
J	V	H	A	A	G	L	E	V	U	L	U	H	D	S
Y	E	G	I	E	X	D	L	F	N	O	R	S	M	E
A	X	Z	U	M	O	R	U	T	I	S	E	R	P	Y
D	V	S	K	C	O	J	L	O	R	T	E	P	H	X

Wordsearch

FIND THE FOLLOWING WORDS...

INTENSIVE
SKYSCRAPER
MINE
SHARK
LOCKDOWN
EGYPT
CODE
MRSA
HYPNOTISE
PLANET
YACHT
PETROL

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 Cerebrum
Q2 390 years
Q3 Napoleon's soldiers
Q4 Jupiter
Q5 50 million years
Q6 £10

WHAT IS IT? ...A BEE

WIN!
A SCALEXTRIC BUNDLE

This month we are giving you the chance to win a Scalextric Spark Plug Batman vs Joker race set and extension packs. Battle it out on the race track with these two famous adversaries using the Spark Plug Dongles to control racers using your Android or iOS smart devices.

© Scalextric

For your chance to win, answer the following question:

Which of the following countries has the highest population of people?

a) **Russia** b) **China** c) **New Zealand**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 30 July 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **futuretcs.com**. Entries must be received by 00:00 BST on 30/07/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

HOW TO...

Practical projects to try at home

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Send your ideas to...

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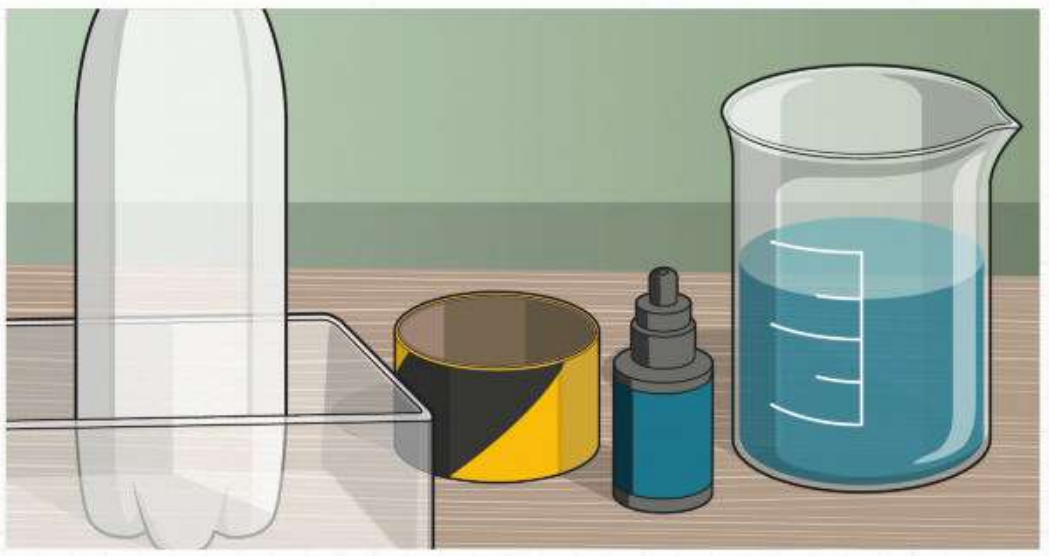
How to make a tornado in a bottle

Six simple steps to creating your own meteorological marvel

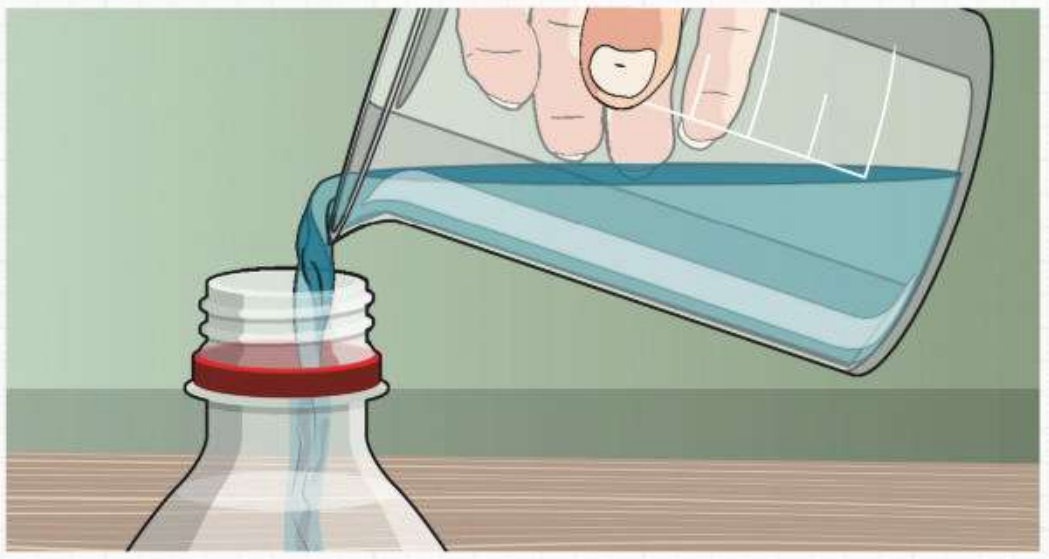


1 Gather your equipment

For this experiment you will need two plastic bottles, one sports bottle cap with an open mouth piece, sticky tape, food colouring and water. If you don't have a sports bottle cap you can use a regular bottle cap, but make sure to create a small hole in it for water to get through.

2 Attach bottle cap

Place the bottle cap upside down onto one of the bottles. Hold this in place as you attach it with sticky tape. This needs to be a watertight seal around the edge to avoid spillages.



3 Add your colour

Before filling the other bottle, add your chosen food colouring to give your tornado the look you want. Then fill the second bottle to the top with water, which will mix with the food colouring.

4 Connect the two bottles together

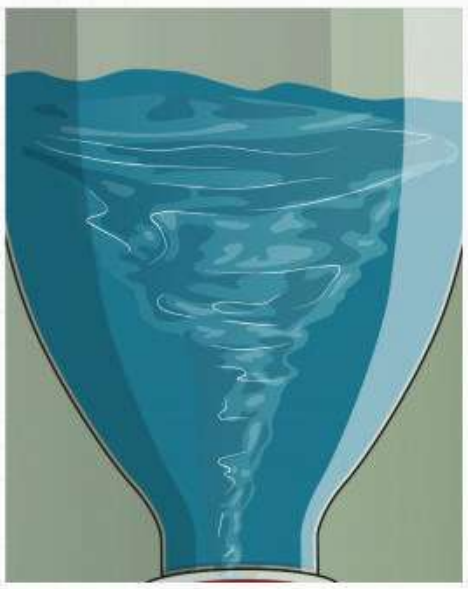
Screw the empty bottle on top of the water-filled one, making sure they are attached securely.

5 Flip the bottles

Turn your bottle tower upside down so that the water is on top. With the bottom bottle full of air, the water is trapped in the top.

6 Create the tornado

Shake the two bottles in a circular motion. This makes the water in the top bottle spin out of the way, creating a path for the air to flow upwards and forming a tiny tornado.



SUMMARY

The shape of the flowing air is formed by the spinning movement and the narrow gap between the bottles. The food colouring creates a cool look, as well as making the tornado more visible. You can also add other items such as glitter to personalise your tornado.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE

Grow your own avocado tree

© Illustrations by Ed Crooks

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INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com

WIN! A HAYNES MANUAL

From cars, to space shuttles, to the Millennium Falcon: Haynes guides take all sorts of vehicles apart and show the reader exactly how they work and how to maintain and repair them.

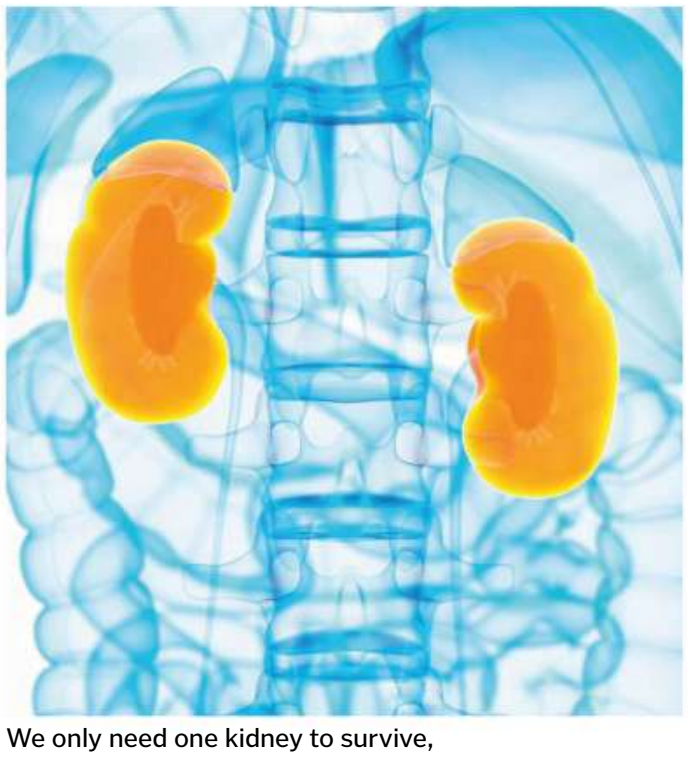
Kidney discovery

Hi **HIW,**

My grandson Solomon, who is nine years old, was reading your article to me about the 38-year-old man who has three kidneys. According to the article only 100 people are reported to have this condition. Then I remember my 64-year-old sister has the same condition. He called her and excitedly told her how unusual she was and read the article to her. He loves reading, and **How It Works** is just perfect for young, thirsty minds.

Pam Johnson

In our last issue, our news section told of a Brazilian man who, after getting his back pain checked out, found out he had a third kidney. It was great to hear of Solomon learning about people with this rare condition and then finding out about another of these amazing cases that was much closer to home. We hope that he continues to enjoy the magazine and remains inspired by the world around him.



© Getty

We only need one kidney to survive, but most people have two

Letter of the month

Nye's nature

Hi **HIW,**

My name is Nye and I am seven years old. I live in Cardiff. I borrow **How It Works** from my school and read it with my parents. My teacher suggested I keep a nature diary during lockdown and I thought you might like to see some of it. I really enjoy doing the drawings.

Nye Moody

We loved reading all about your encounters with nature and the lessons you are learning every day from the natural world around you. Your diary is so well written and serves as a great insight into how much you are continuing to learn during this time when many children are not in school. Using your artistic talent, you have really captured these animals through your illustrations. Keep up the good work, Nye!

© Nye Moody

Our young reader has also written about slow worms, golden-legged grasshoppers and growing his own vegetables

Animal chat

Hi **HIW,**

How come we have no way of understanding or communicating with animals? Wouldn't constant repetition and analysis of their own unique sounds give us this ability?

Faaris Haque

While there have been many attempts to train apes to use sign language and parrots to speak to us, many of the sounds made by animals are alien noises to our ears. Scientists are trying to achieve what you ask by studying and analysing the noises of specific species. One scientist is believed to have succeeded in making sense of the noises made by prairie dogs, but there is a lot of analysis work to be done before we can be sure that these findings are correct. Different species have different abilities, including the likes of dolphins, who can make sounds our ears aren't even able to hear, let alone analyse.

Some people hold the view that animals have no language at all, or that the feat is impossible. Others want to bridge a gap between humans and animals. Maybe one day we will break down more of these interspecies language gaps, but it could be a long and complex process.

© Getty

Animals' body language has been studied to determine physical communication

NEXT ISSUE... Issue 141 on sale **6 AUG 2020**

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Finger facts

Hi **HIW,**

I have two questions actually. I was reading one of your magazines and I saw two things in the 'Fast Facts' section that confused me.

1. 'Your palm and the underside of your fingers cannot tan.' Why is this?
2. 'You have no muscles in your fingers.' How do I move my fingers?

Abigail

These are good questions, and ones that our Fast Facts are designed to make you think about. For your first question, the palms of your hands and bottom of your feet both remain pale no matter how tanned the rest of your body may become. This is because the skin on human hands and feet is thicker, stopping the same amount of UV light from reaching the layers beneath.

Your bewilderment at the second fact is also understandable, as we use muscles for all physical movement. The difference in our fingers is that the muscles used to move them are found in the palm and the forearm, not the fingers themselves. There are tendons in the fingers to relay this movement.

'Clouds of joy'

Hi **HIW,**

I have been enjoying watching the changes in nature during lockdown. I have seen the bleating lambs never leaving their mother's side growing into independent fluffy grass-munchers. Being among nature has been great for keeping a good mental health during this time, and what better company than these walking woolly clouds of joy.

Cameron

Thank you for your letter and for sharing your lovely photograph. In recent weeks, as seasons have begun to change, many of us have spent time appreciating the simplicity of nature. As you have noticed, lambs are hugely dependent on their mothers during the early stages of their lives. This behaviour helps to ensure their survival, and the bleating noise you hear is them building recognition of each other's vocals. We hope you continue to enjoy and appreciate your noisy neighbours.

One of our readers shared this photograph, taken during time observing local sheep

© Cameron

What's happening on... social media?

On social media this month we asked you: What changes to nature have you noticed since the world entered lockdown?

@zidaneyvt4
The sky looked more blue

@joxley7
More bees in our garden and less seagulls inland

@danielj868
Woodpeckers in our garden more frequently, more rabbits around on grass verges

Debi N
I can hear birds singing...

Raúl Espínd
Crickets and hummingbirds have returned to the gardens and squares of my neighbourhood. They certainly make the days and nights more endurable

Graham J
Wood pigeons are more confident and relaxed with less traffic around

Jason P
More deer around the outskirts of the city with less traffic

@maia_h3
I wake up to birds singing instead of the sound of the motorway

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

20x

FLORENCE NIGHTINGALE REDUCED SOLDIER DEATH RATES FROM 1 IN 2.5 TO 1 IN 50 WITH HER INTENSIVE CARE WARD

43,363KG

THE LARGEST CONVENTIONAL LANDMINE HELD OVER 40 TONNES OF EXPLOSIVES

1905

THE FIRST ROADSIDE PETROL PUMPS WERE INSTALLED OVER 100 YEARS AGO IN ST LOUIS, MISSOURI

$24,000

BURJ KHALIFA'S ROYAL SUITE COSTS A SMALL FORTUNE TO STAY IN FOR JUST ONE NIGHT

318

NOT MANY GERMAN ENIGMA MACHINES SURVIVED THE WAR, OF WHICH 34 WERE NEVER USED

MERCURY'S CORE HAS MORE IRON IN IT THAN ANY OTHER PLANET IN THE SOLAR SYSTEM

STOATS CAN MESMERISE RABBITS THEY HUNT WITH A CRAZY DANCE

12 METRES

'THE WORLD'S LITTLEST SKYSCRAPER', THE NEWBY-MCMAHON BUILDING IN TEXAS, IS NEARLY 70-TIMES SMALLER THAN BURJ KHALIFA

2600BCE

SOME OF THE WORLD'S OLDEST PYRAMIDS WERE BUILT OVER 4,000 YEARS AGO IN PERU

7µm

THE SMALLEST MRSA SUPERBUGS ARE LESS THAN ONE-THOUSANDTH OF A CENTIMETRE LONG

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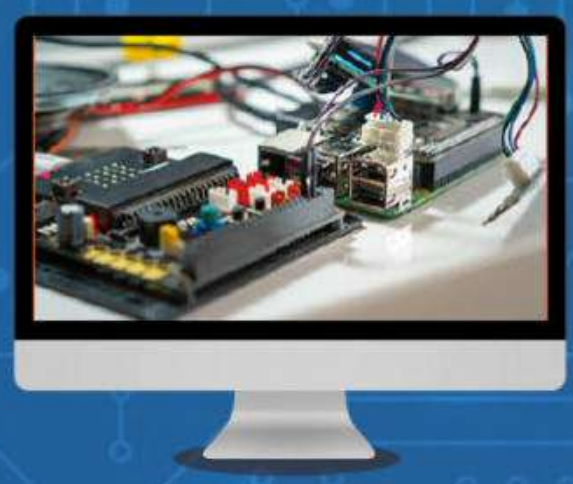

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